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DOWNSTREAM MOVEMENT OF RECENTLY TRANSFORMED SEA LAMPREYS, *PETROMYZON MARINUS*, IN THE CARP LAKE RIVER, MICHIGAN[1]

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Abstract

In order to obtain more precise information concerning the downstream movement of recently transformed sea lampreys, a trapping device was operated in the Carp Lake River, Emmet County, Michigan, from October, 1948, to July, 1951.

The period of downstream migration typically extends from the latter part of October to the middle of April. It varies, however, from year to year with climatic conditions. A few migrants usually appear every day during this period but a sudden increase in water level is characteristically accompanied by a surge in downstream movement of newly transformed sea lampreys. This phenomenon is realized principally during the spring floods and often concurrently with autumn rains and mid-winter thaws.

A total of 7,969 downstream migrants were taken in the 1948-49 season; 16,235 in 1949-50, and 15,103 in 1950-51. Measurements of representative samples from the total catch of sea lamprey migrants of the 1948-49 and 1949-50 seasons revealed a range in length of 95 to 190 millimeters and an average length of 145 millimeters (3.7 to 7.5 inches; mean —5.7 inches).

Introduction

The invasion of the upper Great Lakes by the parasitic sea lamprey, its explosive increase in these waters, and the destructive effects of its attacks upon commercial and game fishes have been adequately reviewed in many recent reports. A comprehensive study of the biology of the lamprey is basic to the current program aimed at reducing the numbers of this destructive predator. These investigations were designed to gain information on the life history, habits, and physiology of the parasite that might contribute toward the development of more effective control methods. The downstream migration of each succeeding year class of newly transformed individuals is considered to be one of the most vulnerable stages at which the species may be attacked. Destruction of sea lampreys at this time has the advantage of eliminating the entire annual production of young from a watershed before they enter upon the parasitic phase of their existence.

At the inception of these studies, there was some uncertainty about the precise time downstream movement of recently transformed, adult sea lampreys occurred. Furthermore, ecological factors influencing

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[1] Contribution from the Michigan Institute for Fisheries Research.

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these movements were unknown. Occasional field observations and studies of larval populations suggested that this movement took place during the winter and/or spring months. In order to obtain more information on this phase of the life cycle, a trapping device was operated in the Carp Lake River, Emmet County, Michigan, from October, 1948, to July, 1951. A preliminary analysis of the runs occurring in the 1948-1949 season in this stream and in the Ocqueoc River, Presque Isle County, Michigan, has been presented by Applegate (1950). The present report concerns the downstream movements in the Carp Lake River during three consecutive seasons.

Support for this study was provided initially by the Michigan Institute for Fisheries Research which constructed the original trapping device and operated the structure until January, 1950. Thereafter, the study was carried on as a cooperative project between that organization and the U. S. Fish and Wildlife Service.

THE CARP LAKE RIVER DAM AND INCLINED-SCREEN TRAP

The Carp Lake River which drains into the Straits of Mackinac on its southwest shore arises about 9 miles from the straits in Carp Lake. This lake has an area of 1,823 acres and one small tributary, Mud Creek. A moderately large spawning run of sea lampreys was observed in this river in 1947 and extensive spawning activity was noted. This fact and the presence of extensive areas of suitable larval habitat suggested that the potential stock of downstream migrants might be large enough to justify the construction of a trapping device.

The trapping device selected for this experiment required the construction of a dam. The lowest suitable site was about 1,500 feet above the mouth of the river where the stream was 32 feet wide. Little spawning occurred below this site in 1947. During the period January-May, 1948, a wooden dam 60 feet wide and 5½ feet high, was constructed on this location. The wall of the dam was constructed of a double row of 2- by 6-inch, tongue-and-groove planks supported by round timbers. A spillway, 15½ feet wide, 2 feet deep, and 9½ feet long carried the water passing over the dam. Bracing timbers and large rocks piled against the downstream side gave the dam wall additional support.

The trapping device was composed of a sloping screen and a trap box. The former consisted of a 1½-inch angle-iron frame, 15½ feet long and 30 inches wide, over which two layers of wire screen were stretched taut with a hydraulic jack. The lower layer was of ½-inch mesh, hardware cloth and the surface layer was of 18-mesh/inch copper screen. This screen unit was installed 6 inches below the lip of the spillway and inclined downward and downstream at a 12° angle. An additional unit, 12 inches wide, was added later to carry larger water volumes. Below the lip of the screen and along its full width, a trap box was built. This box measured 30 inches wide by 24 inches deep and was lined with 14-mesh/inch screen. The level of the floor of the box was above normal water levels in the stream.

All water passing over the spillway fell almost vertically through the screen. Algae, fine detritus, and silt were forced through the screen by the impact of the water. The slope of the screen and the action of the water caused all larger items including lampreys coming down on the current to be forced off the screen into the trap box. The screen itself was entirely self-cleaning and required little attention. Fish and lampreys accelerated their movement off the screen by wriggling or flopping movements. During the winter months, ice did not form upon the inclined screen in such a manner as to hamper its function. The entire device operated satisfactorily during long periods of cold weather with only one modification. The box was replaced with a simple wooden baffle plate (15 inches high) placed across the foot of the inclined screen. The thin coat of ice that formed on this baffle could be removed. Lampreys, fish, and detritus collected in a windrow at the base of the plate. In the summers of 1949 and 1950 the entire structure was converted to a permanent device by the addition of steel sheet-piling in the dam wall, widening of the spillways, and the use of concrete in all spillways and screen supports (Figure 1).[2]

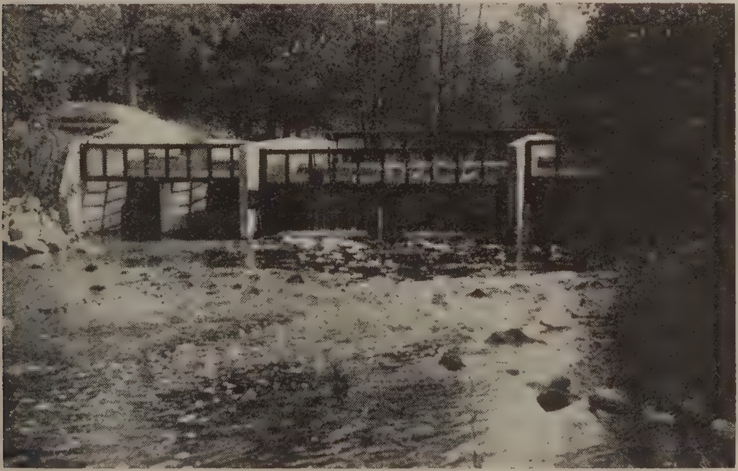

FIGURE 1.—Dam and inclined-screen sea lamprey trap in the Carp Lake River, Emmet County, Michigan (Final, improved structure).

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[2] Development of the principle of operation of this trapping device is credited to Mr. Philip Wolf of Malmoe, Sweden.

The dam and trap was inspected once to three times each day by an attendant. Records were kept of all lampreys, fish, reptiles, and mammals taken. All lampreys were preserved in 10-percent formalin for later examination. Air and water temperatures (taken with maximum-minimum thermometers), water-level-gauge readings, and observations upon the weather and general conditions prevailing in the watershed were taken daily.

A total of 39,307 fully transformed sea lampreys, 67 partly transformed sea lampreys, 517 adult lampreys of other species, 21,663 larval lampreys, and 13,319 other fish were captured during the entire period of operation. Of the fully transformed sea lampreys, 7,969 were taken during the 1948-1949 season, 16,235 in the 1949-1950 season, and 15,103 in the 1950-1951 season.

THE DOWNSTREAM MOVEMENT AND FACTORS AFFECTING MIGRATION

The downstream movement of recently transformed sea lampreys usually begins during the last week in October or the first week in November, extends through the winter and early spring months, and ends during the early part of April. Only a few scattered individuals migrate before or after this season. The migration is usually greatest during late March and early April with a lesser peak of activity in November. During the intervening winter months, a few come downstream nearly every day. Sudden minor spurts of activity may also occur during this period.

Most increases in movement appear to be associated with rising or fluctuating water levels. Late fall rains which increase the flow bring down the initial surge of newly transformed individuals. Flood conditions resulting from mid-winter thaws and rains are often accompanied by sudden increases in downstream movement. The greatest downstream migration occurs on the rise and crest of the floods resulting from the general spring break-up in late March or early April. For this reason, the calendar dates of the migration vary from year to year and from one watershed to another.

Although nearly all of the downstream migration occurred after the mean daily water temperature had fallen below 41° F., there was no evident relationship between changes in water temperature and the amount of migratory activity.

Of the following descriptions of the migrations of newly transformed sea lampreys in the seasons of 1948-49, 1949-50, and 1950-51, all are illustrated by diagram but to avoid the presentation of an excessive amount of tabular material, daily records of data are given for the 1949-50 season only.

In the Carp Lake River in the 1948-1949 season, a single fully transformed sea lamprey came downstream into the trap on October 7, 1948; two additional individuals were taken on October 21 and October 23

(Fig. 2). Sustained downstream movement began on November 2, reached a sharp peak on November 21, and then subsided with equal rapidity. Some movement continued until December 9. The early portion of this period was characterized by rising water levels resulting from light rains and wet snow. Heavy rains from November 17 to 19 increased the volume of flow. The flood crested on the night of November 20-21 and on that night a sudden surge of migrants appeared (3,467 individuals between nightfall and daylight). Subsiding water levels were accompanied by a decline in migration until December 9. From this date until March 22, 1949, downstream movement was of a minor nature. Between January 17 and 24, cold rains increased the flow in the river. Most of this water was passed downstream on top of the ice which had covered nearly all of the river since mid-December. A similar condition prevailed between February 23 and 27 as a result of snow, sleet, rains, and a light thaw. Both of these brief increases in volume of flow were accompanied by spurts of downstream migration.

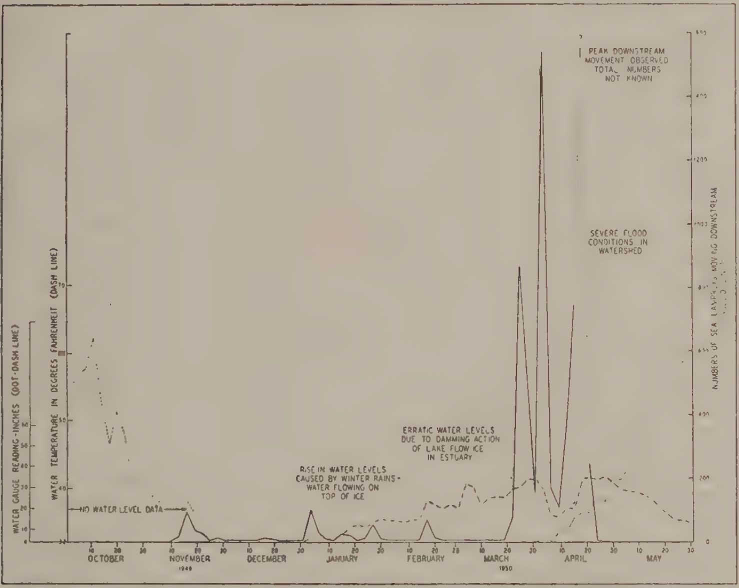

FIGURE 2.—Numbers of recently transformed sea lampreys migrating downstream in the Carp Lake River and fluctuations of water level and water temperature during the 1948-1949 season. All points based on 3-day means. Scales were so computed that the sums of the vertical distances above the base are the same for all three variables for the days with full records.

Warm winds in the Carp Lake region from March 20 to 25 were followed by severe flood conditions as snow and ice melted rapidly. Water levels rose abruptly on March 22. The major downstream movement of lampreys began. On March 26, the water overtopped the dam, undercut one wing, and destroyed the trap box. The structure was not restored to full operating efficiency until April 18. During the period March 26-April 3, a great number of downstream migrants was observed passing over the dam during the daylight hours. Many of these accumulated under the lip of the spillway and behind the stream of falling water. This space, triangular in cross section, had a base on the screen about 5 inches wide. On March 26, 24 hours after the flood over-topped the dam, access was gained to a 30-inch length of this air space. We removed 614 sea lampreys from this limited area. It was also determined visually that an equivalent concentration was trapped beneath the entire lip of the spillway. It is estimated, therefore, that between 3,000 and 4,000 migrants had accumulated in this small air pocket in the first 24 hours after the trap had been rendered inoperative. This number represents only a small fraction of the total number that passed downstream.

A few sea lampreys were observed migrating during daylight hours between April 3 and 10; thereafter, none were seen. Water levels declined during this period and on April 18, when the trap was again operative, they had receded to about mean spring levels. Between April 19 and 23, seven individuals came downstream. From the latter date until June 30, when these records terminate, no others appeared.

In the 1949-50 season, migratory activity began when two fully transformed individuals came downstream on November 1, 1949 (Fig. 3, Table 1). Scattered migrants moved downstream until November 14 when rains and melting snow raised the river level. In the succeeding 3 days this season's first surge of migrants appeared in the trap. This surge gradually subsided as water levels receded during the balance of the month. Freezing temperatures stabilized water levels until January 3, 1950, when winter rains increased the volume of flow. Concurrently with this minor mid-winter flood there was a low peak of downstream movement. Thereafter a sustained and severe drop in air temperature caused the river to freeze throughout its entire course making it necessary for any excess water to flow on top of the ice. Intermittent rain, sleet, and brief thaws from January 14 to 29 aided in maintaining high and fluctuating water levels. This period produced two minor peaks in lamprey movement corresponding to the two peak flood levels. A similar situation prevailed between February 13 and 23, as a result of snow storms and subsequent thaws.

An upward trend in air temperature beginning March 20 precipitated the spring break-up and major flood conditions prevailed. On March 22, the principal downstream movement of the season began. This migration continued in a sustained but fluctuating manner until April 18. From the latter date until April 22 the trapping screens were removed from the dam to permit the passage of an unprecedented flood. A considerable number of migrants passed downstream during the early part of this 3-day period. After the resumption of trapping operations on April 22 only scattered migrants were taken until May 31; thereafter no others appeared.

The downstream movement of newly transformed sea lampreys in the 1950-51 season began September 22, 1950 (Fig. 4). Only scattered migrants were trapped until November 1, when a slight rise in water level apparently stimulated a more or less sustained movement downstream. Rain and melting snow during this period greatly increased the volume of flow until about December 15. During the entire period the numbers of migrants fluctuated closely in accordance with changes in volume of water flow.

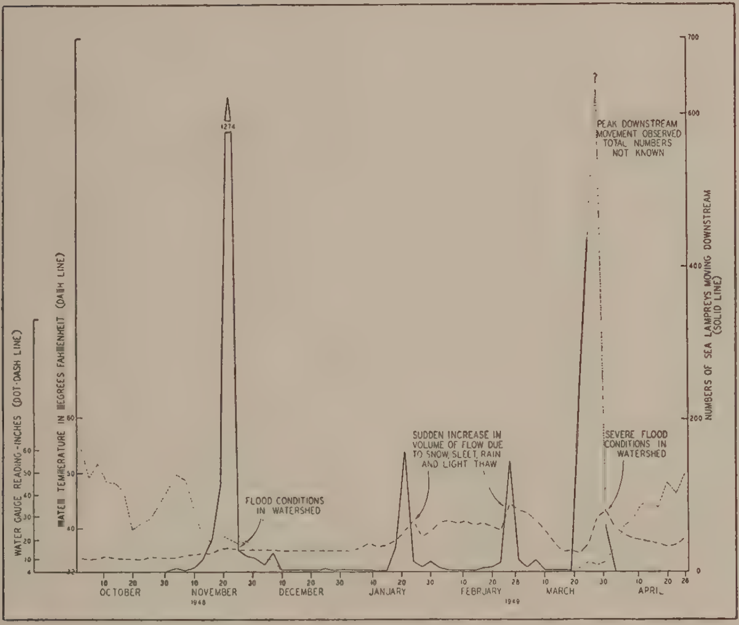

FIGURE 3.—Numbers of recently transformed sea lampreys migrating downstream in the Carp Lake River and fluctuations of water level and water temperature during the 1949-1950 season. All points based on 3-day means. Scales were so computed that the sums of the vertical distances above the base are the same for all three variables for the days with full records.

The next noticeable increase in migration was on February 26, 1951. On and after this date water levels rose several times with periods of thawing weather. On March 28 the major break-up began and severe flood conditions prevailed during the following month. Apparently the bulk of the migrants passed downstream during the first 12 or 13 days after the break-up began. Maximum flood conditions actually were not reached until April 13 when it became necessary to discontinue operation of the trap for several days. According to the weir attendant, only a few lampreys were observed coming downstream during this period. From April 18, when trapping operations were resumed, until the last day of May only a few stragglers were taken in the trap; thereafter none was taken.

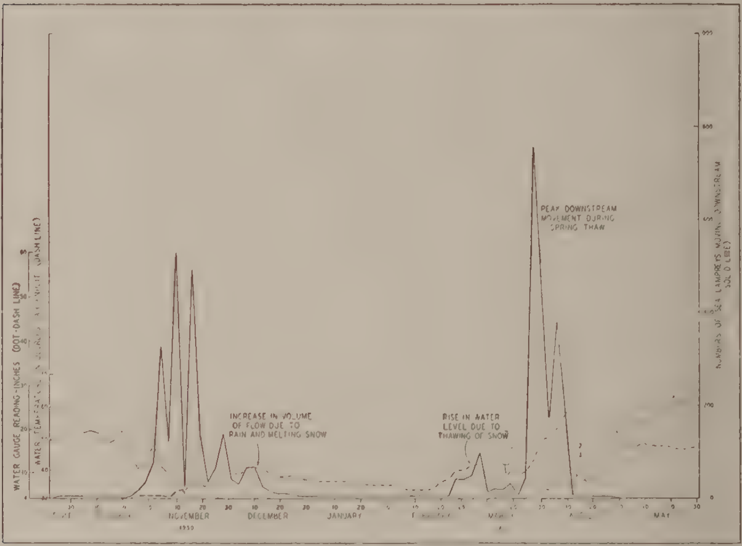

FIGURE 4.—Numbers of recently transformed sea lampreys migrating downstream in the Carp Lake River and fluctuations of water level and water temperature during the 1950-1951 season. All points based on 3-day means. Scales were so computed that the sums of the vertical distances above the base are the same for all three variables for the days with full records.

According to observations made during the three seasons' migrations in the Carp Lake River, the initial surge of downstream movement in November occurred during declining water temperatures when the daily mean was 41°F. or lower. The single exception was noted in 1950 when 261 lampreys came downstream on November 3 although the mean water temperature was 44°F. Mid-winter increases in downstream movement occurred at water temperatures which were stabilized very near 32°F. The greatest movement, in late March and early April, took place during periods of rising water temperatures and almost entirely at daily means below 41°F. Since there appears to be no relationship between fluctuations in water temperature and the amount of migratory activity, these temperatures are merely coincident with the season when the lampreys have attained full transformation and are ready to move downstream. All evidence accumulated thus far indicates that the stimulus for this movement is provided primarily by sudden increases in the stream flow. At times only a small rise in water level will cause an appreciable number of individuals to start their journey downstream.

Length and Weight of Migrants

All recently transformed sea lampreys taken on every other day in the 1948-49 and 1949-50 seasons in the Carp Lake River were measured for total length to the nearest millimeter. A total of 2,482 individuals of the 1948-49 run and 2,492 specimens of the 1949-50 run were examined. Fully transformed downstream migrants taken from this stream in the 1948-49 season ranged from 95 to 189 millimeters in total length and averaged 143.6 millimeters (S.D., ± 10.8 millimeters) (3.7 to 7.4 inches; mean — 5.7 inches); those of the 1949-50 season ranged from 103 to 191 millimeters and averaged 145.2 millimeters (S.D. ± 11.6 millimeters) (4.1 to 7.5 inches; mean — 5.7 inches). The length frequency distributions of the annual samples were unimodal, and the frequency polygons for both are quite symmetrical (Fig. 5). The polygons exhibit neither the bimodality nor the irregular "flattening" that might be expected if sexual difference in length existed at this phase of the life cycle.

A progressive increase in the size of migrants evidently occurs during the period of downstream movement. Comparisons of length-frequency distributions for each month and of the mean lengths of the daily samples (Table 1) indicate that the smallest individuals usually moved downstream in the fall. A general increase occurred in the average total length during the winter months and was greatest during late winter and early spring when migratory activity was at its peak.

One sample consisting of 216 migrants was taken on November 20, 1948, and each individual was weighed on a dietary scale to the nearest 0.1 gram. The weights of the individuals varied from 2.3 grams to 8.4 grams and averaged 4.1 grams. Their total lengths ranged from 121 to 172 millimeters and averaged 143.0 millimeters.

Habits and Behavior

One of the most striking characteristics of the migration of newly transformed sea lampreys is the suddenness with which large numbers of individuals leave the mudbanks and move downstream. Under the impetus of rising waters, a virtual "emergence" takes place and large numbers of the small lampreys travel downstream on the rise and crest of the floodwaters. This surge frequently ends as suddenly as it began.

TABLE 1.—*Numbers and minimum, average, and maximum total lengths of newly transformed sea lampreys migrating downstream in the Carp Lake River during the winter of 1949-50, with weather, water-temperature and water-level data for the period* [*Readings and observations made at 8:00 a.m. each day*].

Date 1949-1950	Mean water temperature (Deg. F.)	Water level (inches)	Weather	Number taken	Sea lampreys Total length (millimeters)		
					Minimum	Average	Maximum
Nov. 1	40.0	....	Clear	2	142	145.5	149
2	40.0	....	Overcast	1	....	....	....
3	38.5	....	Overcast	0	....	....	....
4	37.5	....	Snow	1	....	(129.0)	....
5	36.5	....	Clear	0	....	....	....
6	37.0	....	Overcast	2	135	146.0	157
7	38.0	....	Clear	0	....	....	....
8	41.0	....	Clear	0	....	....	....
9	42.5	....	Clear	0	....	....	....
10	39.0	....	Clear	3	130	146.7	170
11	42.0	....	Overcast	1	....	(136.0)	....
12	43.0	....	Overcast	1	....	(125.0)	....
13	42.0	....	Rain	7	128	141.6	150
14	40.0	....	Snow	50	....	....	....
15	39.0	....	Snow	96	120	147.0	175
16	38.0	....	Overcast	133	....	....	....
17	38.0	4.0	Overcast	45	126	146.5	165
18	37.0	4.0	Overcast	32	....	....	....
19	36.0	4.0	Overcast	43	116	146.2	188
20	35.0	4.2	Overcast	30	....	....	....
21	35.0	4.2	Overcast	40	....	....	....
22	34.5	4.2	Overcast	12	....	....	....
23	32.5	4.5	Overcast	24	116	132.4	152
24	32.0	4.5	Overcast	8	....	....	....
25	32.0	4.5	Overcast	7	128	142.3	165
26	32.0	4.5	Overcast	8	....	....	....
27	32.0	4.2	Snow	12	125	141.6	154
28	32.0	4.0	Overcast	13	....	....	....
29	32.0	4.0	Rain	18	124	142.4	160
30	32.5	4.2	Overcast	6	....	....	....
Dec. 1	32.0	4.2	Overcast	3	121	140.0	157
2	32.0	4.0	Snow	2	....	....	....
3	32.0	4.0	Overcast	1	....	(149.0)	....
4	32.0	4.0	Rain	2	....	....	....
5	32.0	4.0	Snow	2	147	147.5	148
6	32.0	4.0	Overcast	0	....	....	....
7	32.0	4.0	Clear	5	132	140.4	153
8	32.0	4.0	Overcast	3	....	....	....
9	32.0	4.0	Overcast	6	129	140.5	151
10	32.0	4.0	Overcast	3	....	....	....
11	32.0	5.0	Rain	6	126	146.0	159
12	32.0	5.0	Overcast	0	....	....	....
13	32.0	5.0	Overcast	6	130	142.0	158
14	32.0	5.0	Overcast	16	....	....	....
15	32.0	5.0	Overcast	15	126	148.2	161
16	32.0	5.0	Overcast	7	....	....	....
17	32.0	5.0	Overcast	14	127	141.3	160
18	32.0	5.0	Rain	14	....	....	....
19	32.0	4.5	Overcast	10	132	144.6	158
20	32.0	4.5	Overcast	6	....	....	....
21	32.0	4.5	Overcast	3	134	142.0	156
22	32.0	4.5	Snow	4	....	....	....
23	32.0	4.0	Overcast	3	132	145.7	155
24	32.0	4.0	Overcast	2	....	....	....
25	32.0	4.5	Overcast	5	126	143.6	162
26	32.0	4.5	Overcast	5	....	....	....
27	32.0	4.0	Snow	1	....	(129.0)	....
28	32.0	4.0	Overcast	10	....	....	....
29	32.0	4.0	Clear	3	139	159.3	171
30	32.0	4.0	Clear	2	....	....	....
31	32.0	4.5	Rain	0	....	....	....
Jan. 1	32.0	4.5	Rain	1	....	(136.0)	....
2	32.0	4.5	Rain	2	....	....	....
3	32.0	7.0	Rain	118	124	144.1	179
4	32.0	6.0	Overcast	228	....	....	....
5	32.0	5.5	Snow	61	123	149.2	175

TABLE 1.—*Continued*

Date 1949-1950	Mean water temperature (Deg. F.)	Water level (inches)	Weather	Number taken	Sea lampreys Total length (millimeters)		
					Minimum	Average	Maximum
Jan. 6	32.0	5.5	Overcast	26	....	....	....
7	32.0	5.5	Clear	5	149	154.0	159
8	32.0	5.5	Clear	12	....	....	....
9	32.0	7.0	Clear	10	140	151.6	171
10	32.0	6.0	Rain	4	....	....	....
11	32.0	6.0	Overcast	3	141	143.7	148
12	32.0	6.0	Overcast	2	....	....	....
13	32.0	6.0	Rain	6	140	152.8	163
14	32.0	7.0	Rain	4	....	....	....
15	32.0	8.0	Snow; rain	43	129	150.0	173
16	32.0	7.0	Snow	26	....	....	....
17	32.0	11.0	Clear	45	132	151.3	183
18	32.0	11.0	Snow	16	....	....	....
19	32.0	11.0	Snow	4	139	148.3	159
20	32.0	12.0	Snow	2	....	....	....
21	32.0	12.0	Snow	4	135	151.8	161
22	32.0	12.0	Overcast	10	....	....	....
23	32.0	12.0	Snow	15	128	149.4	182
24	32.0	10.0	Snow	5	....	....	....
25	32.0	12.0	Overcast	18	127	144.7	185
26	32.0	12.0	Overcast	45	....	....	....
27	32.0	12.5	Clear	65	126	144.0	179
28	32.0	15.0	Overcast	49	....	....	....
29	32.0	14.5	Snow; rain	12	121	138.3	156
30	32.0	14.5	Clear	10	....	....	....
31	32.0	16.0	Snow	7	137	149.9	165
Feb. 1	32.0	14.0	Clear	5	....	....	....
2	32.0	14.0	Clear	6	127	146.8	168
3	32.0	15.0	Clear	3	....	....	....
4	32.0	15.0	Clear	2	133	134.5	136
5	32.0	14.0	Overcast	2	....	....	....
6	32.0	14.0	Overcast	5	127	138.0	159
7	32.0	13.5	Clear	1	....	....	....
8	32.0	13.0	Clear	3	129	148.0	160
9	32.0	13.0	Overcast	3	....	....	....
10	32.0	15.0	Overcast	1	....	....	....
11	32.0	15.0	Overcast	4	....	....	....
12	32.0	14.0	Snow	7	....	....	....
13	32.0	14.0	Overcast	11	133	146.8	163
14	32.0	16.0	Snow	7	....	....	....
15	32.0	14.0	Snow	0	....	....	....
16	32.0	24.0	Overcast	75	126	147.9	172
17	32.0	24.0	Overcast	110	....	....	....
18	32.0	23.0	Overcast	20	119	145.8	171
19	32.0	22.0	Snow	10	....	....	....
20	32.0	20.0	Clear	16	131	152.1	173
21	32.0	23.0	Snow	14	....	....	....
22	32.0	22.0	Snow	5	140	153.6	184
23	32.0	21.0	Overcast	6	....	....	....
24	32.0	17.0	Snow	4	138	150.5	165
25	32.0	21.0	Snow	2	....	....	....
26	32.0	22.0	Snow	0	....	....	....
27	32.0	23.0	Clear	2	....	....	....
28	32.0	20.0	Snow	1	....	(137.0)	....
Mar. 1	32.0	20.0	Snow	3	128	137.0	148
2	32.0	20.0	Snow	4	....	....	....
3	32.0	32.0	Clear	6	120	134.3	163
4	32.0	32.0	Overcast	7	....	....	....
5	32.0	30.0	Clear	1	....	(142.0)	....
6	32.0	29.0	Clear	0	....	....	....
7	32.0	32.0	Overcast	2	....	(153.0)	....
8	32.0	30.0	Snow; rain	3	....	....	....
9	32.0	18.5	Clear	2	139	145.5	152
10	32.0	22.0	Clear	4	....	....	....
11	32.0	24.0	Snow	1	....	(158.0)	....
12	32.0	25.0	Clear	1	....	....	....

TABLE 1.—*Continued*

Date 1949-1950	Mean water temperature (Deg. F.)	Water level (inches)	Weather	Number taken	Sea lampreys Total length (millimeters)		
					Minimum	Average	Maximum
Mar. 13	32.0	25.0	Clear	4	114	133.8	150
14	32.0	25.0	Overcast	4			
15	32.0	25.0	Clear	1		(128.0)	
16	32.0	25.0	Clear	1			
17	32.0	26.0	Snow	5	133	144.0	164
18	32.0	18.0	Clear	3			
19	32.0	28.0	Clear	1		(142.0)	
20	32.0	30.0	Overcast	8			
21	32.0	28.0	Overcast	2			
22	32.0	28.0	Overcast	50			
23	32.0	31.0	Fog	181	126	148.3	175
24	32.0	30.0	Clear	138			
25	32.0	28.0	Clear	100	126	150.3	190
26	32.0	33.0	Overcast	2,365			
27	32.0	32.0	Rain	345	120	148.3	187
28	32.0	36.0	Rain; snow	750			
29	32.0	34.0	Clear	533	122	147.2	178
30	32.0	34.0	Clear	169			
31	32.0	34.0	Overcast	76	121	140.6	168
Apr. 1	32.0	34.0	Snow	214			
2	32.0	36.0	Overcast	299	118	141.1	182
3	32.0	34.0	Overcast	614			
4	33.0	18.0	Snow	3,711	108	138.8	163
5	32.5	17.0	Snow	284			
6	32.0	17.0	Clear	41	117	143.5	172
7	32.0	16.0	Overcast	188			
8	32.5	16.0	Clear	164			
9	33.5	16.0	Overcast	148			
10	34.5	16.0	Rain	9	130	143.9	161
11	34.0	21.0	Rain	19			
12	33.5	20.0	Rain	855	115	140.6	177
13	33.0	19.5	Overcast	219			
14	33.0	19.0	Snow	51	120	144.8	172
15	36.0	19.0	Clear	770			
16	37.0	22.0	Clear	1,426	105	140.2	165
17	37.0	29.0	Clear	794			
[1]18	36.0	35.0	Clear				
[1]19	36.0	38.0	Overcast				
[1]20	35.0	37.0	Rain; snow				
[1]21	36.0	34.0	Overcast				
22	38.0	33.0	Overcast	4			
23	37.0	33.0	Overcast	2			
24	40.0	34.0	Clear	3			
25	40.0	34.0	Rain	5		(147.0)	
26	38.0	36.0	Overcast	6			
27	38.0	36.0	Overcast	0			
28	38.0	34.0	Overcast	0			
29	39.0	34.0	Clear	2			
30	44.0	32.0	Overcast	1			
May 1	42.0	31.0	Overcast	0			
2	40.0	30.0	Clear	0			
3	42.0	29.0	Overcast	2			
4	41.5	28.0	Overcast	0			
5	43.0	28.0	Overcast	1		(177.0)	
6	46.0	29.0	Overcast	0			
7	40.0	28.5	Clear	1		(178.0)	
8	45.0	28.0	Clear	0			
9	46.0	27.5	Rain	1		(130.0)	
10	46.0	28.0	Rain	0			
11	46.0	27.0	Clear	0			
12	49.0	26.0	Clear	1			
13	52.0	26.0	Overcast	0			
14	52.0	25.0	Overcast	0			
15	52.0	24.5	Clear	2	174	176.0	178
16	52.0	24.0	Clear	0			
17	54.0	23.0	Overcast	1			

TABLE 1.—*Continued*

Date 1949-1950	Mean water temperature (Deg. F.)	Water level (inches)	Weather	Number taken	Sea lampreys Total length (millimeters)		
					Minimum	Average	Maximum
May 18	52.0	19.5	Overcast	0	....	....	....
19	53.0	20.0	Clear	0	....	....	....
20	57.0	19.0	Clear	0	....	....	....
21	59.0	18.0	Clear	0	....	....	....
22	62.0	15.0	Clear	0	....	....	....
23	58.0	15.0	Clear	0	....	....	....
24	63.0	14.5	Clear	0	....	....	....
25	62.0	13.0	Clear	0	....	....	....
26	62.0	14.0	Rain	0	....	....	....
27	56.0	15.0	Clear	1	....	....	....
28	57.0	14.0	Clear	0	....	....	....
29	60.0	13.0	Overcast	0	....	....	....
30	62.0	13.0	Clear	1	....	(133.0)	....
31	64.0	13.0	Overcast	2	....	....	....
Total taken and grand average and range of size...				16,235	[2]103	[2]144.7	[2]190

[1] Trap inoperative during April 18-21 due to extreme flood conditions.
[2] Based on 2,492 specimens.

Most of the individuals observed in migration displayed little effort to accelerate their passage downstream. Such swimming activities as they exhibited were casual and intermittent, and some individuals were seen drifting tail-first. Since the whole movement downstream is passive, the speed of emergence and travel downstream must be attributed to the increased volume and velocity of the stream when such movements occur.

Field observations and laboratory examinations indicate that very few young sea lampreys attempt to feed during migration. An exception occurs where large, inland lakes provide conditions suitable for the parasitic phase. At least two such lakes are present in Michigan. Where smaller inland lakes interrupt the downstream journey, the migrants apparently pass through them without attacking the resident fish species. For example, each year many thousands of recently transformed adults pass through Ocqueoc Lake on their way down the Ocqueoc River to Lake Huron. Since 1947, many fish taken at all seasons of the year from this lake have been examined and none have borne scars that could be attributed to downstream migrants. Furthermore, the examination of digestive tracts of 216 recently transformed individuals taken on November 20, 1948, in the Carp Lake River trap yielded no evidence of their having attempted their initial feeding after transformation.

Were it usual for young migrants to begin feeding before reaching the big lakes, there would be many reports of resident stream fish bearing young sea lampreys or their scars. The few reports received were traceable to native species of lampreys or to sea lampreys carried on fish that had migrated into a stream from a large body of water. Certain exceptions have been noted, however. On May 12, 1948, an examination was made of a 5.0-inch, recently transformed sea lamprey which was taken from a rainbow trout caught in the Ocqueoc River, Michigan,

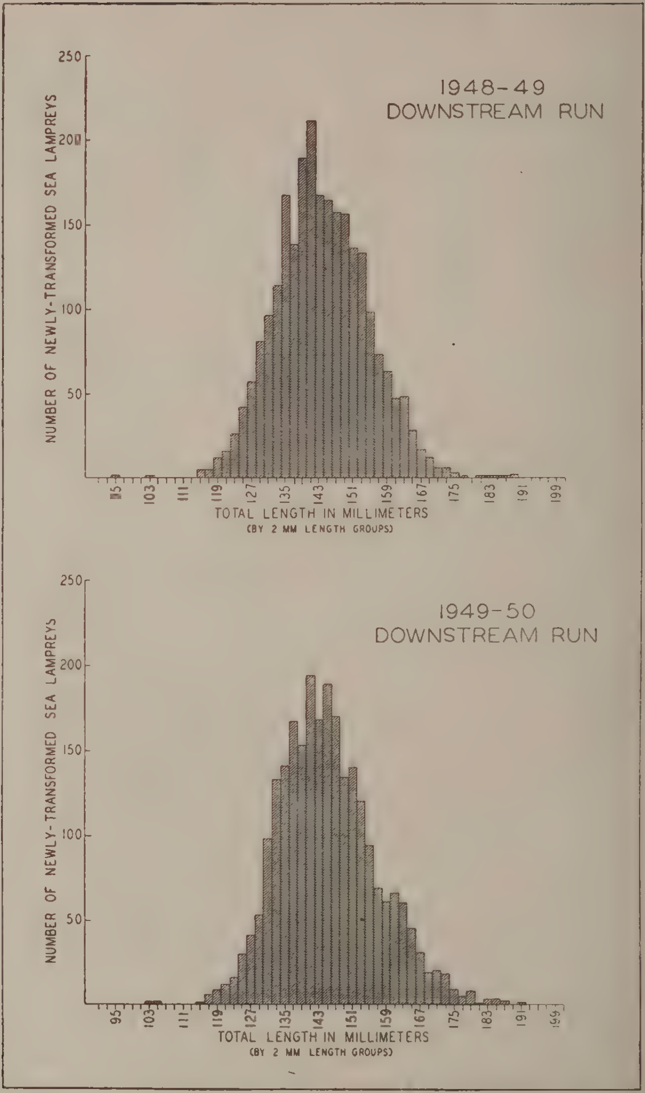

FIGURE 5.—Length-frequency distributions of 2,482 recently transformed sea lampreys taken during their downstream migration in the Carp Lake River in the 1948-49 season and of 2,492 similar individuals taken in the 1949-50 season.

about 5 miles above its estuary. Shetter mentioned four young sea lampreys being found on a rainbow trout caught on July 6, 1945, in the downstream trap of a weir in this river.[3] Gage (1928) reported that lake lampreys, kept in aquaria through their transformation, attacked fish immediately after leaving their burrows in the tank bottom. Similar specimens held by the senior author did not feed until some time after emergence. Those exceptions noted for a Michigan stream are attributed to stragglers of the general downstream movement which did not find their way out of the watershed immediately or to individuals which had been to Lake Huron once and rode back into the stream attached to some fish. Examples of this latter behavior were observed in 1949 when on three occasions young sea lampreys were found attached to migrating white suckers taken in the upstream trap of a weir in the Ocqueoc River.

DOWNSTREAM MOVEMENT OF PARTIALLY TRANSFORMED LAMPREYS AND OTHER SPECIES

During the 1948-49 season, 44 partially transformed sea lampreys were taken in the Carp Lake River trap. Ten came downstream in the 1949-50 season and 13 were taken in the 1950-51 season. Most of these individuals were captured in late July and in the month of August. In view of the time of year at which these individuals were taken, their movement downstream may be related to the shift in stream habitat made by some of the larger larvae and transforming individuals (Applegate, 1950). These observations on the scarcity of partially transformed individuals moving downstream are at variance with similar observations made for one other species. It has been reported to the writers that large numbers of incompletely transformed individuals of the Pacific lamprey, *Entosphenus tridentatus*, accompany the major movements of fully transformed lampreys coming downstream during flood stages.

In the 3-year period of operation, a small number of adults and partly transformed individuals of the silver lamprey, *Ichthyomyzon unicuspis*, were trapped. Nearly all were taken in the months of May and June. A few larvae of this species drifted downstream, principally in the months of April and May. Adults of the American brook lamprey, *Entosphenus lamottenii*, were captured almost exclusively from mid-April through the first week of June. One hundred and ninety-seven were taken in the spring of 1949, 115 in the same season in 1950, and 118 during this period in 1951.

A total of 492 larval lampreys identifiable only as sea lampreys or American brook lampreys were taken during the 1948-49 season. This total increased to 8,403 larvae in 1949-50 and 12,647 larvae in 1950-51. A few of these came downstream in nearly every month of the year. The majority, however, were trapped in April and May. The capture of both partly transformed and fully metamorphosed American brook lampreys along with the larvae make it seem probable that these larvae were predominantly of that species.

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[3] Shetter, David S. Results of the 1945 operations at the Ocqueoc River sea lamprey weir. Typewr. rept., Rept. No. 1015, Mich. Inst. for Fish. Res., 18 p., 1945.

Presumably the American brook lamprey and sea lamprey larvae often occupy the same habitat and during flood conditions many are washed out of their burrows and swept downstream. These displaced larvae are thought to be "total casualties" once they are swept out of the stream and into the lake proper.

In addition to the various lamprey species, 23 species of fish were taken in the trap as they moved downstream. In all, 13,319 fish were caught during the period of trap operation. The principal runs were of white suckers *Catostomus c. commersonnii*, Great Lakes longnose dace, *Rhinichthys c. cataractae*, northern common shiners, *Notropis cornutus frontalis*, lake chubs, *Couesius plumbeus*, smallmouth black bass, *Micropterus d. dolomieu*, and brook stickleback, *Eucalia inconstans*. All but the last species were believed to be spawning-run fish that were returning to the lake. Presumably all had been transferred upstream over the dam at various times during the season.

Of particular interest was the fact that no runs of fishes occurred during the period when the bulk of the newly transformed sea lampreys were coming downstream. Furthermore, during this period downstream movements of resident stream fishes were limited. Of the 13,319 fish trapped in the 3-year period, only 1,798 or 13.6 percent were taken during the period of downstream movement of the young sea lampreys (November 1 to April 30). The remainder (11,521 individuals or 86.4 percent) were taken during the intervening periods when no downstream movement of lampreys was occurring (May 1 to October 31). This fact is of particular significance since it would indicate that devices lethal to all fish life (such as high-voltage electric fish fences), which were designed to destroy downstream runs of newly transformed sea lampreys, would cause little damage among other populations of resident or migrating fish species.

Acknowledgments

The writers wish to acknowledge the assistance of Mr. Albert Gabrielson, of Carp Lake, Michigan, who was trap attendant during the entire period of operation, and the further assistance of Eda S. Applegate and William Gaylord in making the numerous measurements of collected specimens.

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Growth and Mortality Rates in Sibling and Unrelated Oyster Populations

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Abstract

GROWTH CHARACTERISTICS of three different populations of oysters grown near Pensacola, Florida, present some unusual features. The populations described were of the same age and exposed to similar hydrographic conditions for a period of thirteen months. These populations may be described as follows:

Wild oysters resulting from natural set on shell cultch during a 12-hour period; had unlimited supply of water; oysters were crowded; remained on shell cultch throughout the year; kept free from predators but not otherwise handled or cultured.

Cultivated oysters resulting from natural set on flat artificial cultch during a 12-hour period; oysters cleaned regularly and separated from sub-stratum within first two months so that they grew as "singles"; unlimited water supply as above group.

Sibling oysters growing on flat artificial cultch throughout the year; had a restricted but not necessarily inadequate water supply; oysters derived from a single fertilization; kept free from predators, but not otherwise cleaned; oysters were not crowded.

Analysis of total mortalities in the three groups gave the following data: Wild—67 per cent; Cultivated—33 per cent; Sibling—22 per cent. The seasonal occurence of mortality was, however, essentially similar in the three groups. Approximately 70 per cent of total mortality in each group occurred during first four months in the summer. This is correlated with high temperature and salinities and not with age of oysters as shown by fact that similar distribution of seasonal mortality occurs in older oysters in same environment. A somewhat higher mortality during first months of growth of the wild oysters s attributed to crowding.

Analysis of seasonal and total increments in average linear growth of the hree groups showed the populations were remarkably similar. Data were as ollows for final average length at age of 13 months: Wild—52.6 mm., Culivated—59.3 mm. and Sibling—63.7 mm. However, the range of sizes in he three groups was quite different. Wild oysters varied most and showed he greatest length—from 34 to 95 mm., Cultivated—32 to 70 mm. and Sibing—48 to 86 mm.

Graphs illustrating curves of distribution of population sizes show a striking difference in the populations. These may be summarzed as follows:

Sibling oysters showed reasonably normal distribution curve, although tails of the curve were cut short and there was a concentration of the population at the average size. Wild oysters showed a curve with marked shift to the maller sizes although total length attained was greater than in the other two groups. Cultivated oysters showed peculiar frequency distribution in which majority of oysters attained maximum size length. These differences can be explained only on the basis of a combination of both hereditary and environmental factors which influence growth patterns.

DEPARTMENT OF THE INTERIOR
ISH AND WILDLIFE SERVICE
SEP. NO. 335

FURTHER EXPERIMENTS ON THE ESCAPE OF UNDERSIZED HADDOCK THROUGH OTTER TRAWLS

By John R. Clark*

INTRODUCTION

The results of the first of a series of recent experiments on the escape of ock through otter-trawl meshes were reported in the September issue of this al. In that series of experiments, nets with cod ends of $4\frac{7}{8}$- and $5\frac{1}{2}$-inch (between knot centers, new) were tested on two trips of the otter trawler gan in June (1952). This report presents results of experiments with cod of $5\frac{7}{8}$- and $6\frac{3}{8}$-inch (between knot centers) mesh aboard another trawler later e year.

METHODS

The experiments were conducted on a regular fishing trip of the large otter er Wisconsin (fig. 1) from October 14 to 23 on Georges Bank. The procedure wed was essentially the same as used on the Michigan cruises.

A $5\frac{7}{8}$-inch (between knot centers) cod end was used on a standard No. 41 otter with a belly of 5-inch (between knot centers) mesh throughout. A $6\frac{3}{8}$-inch

THE OTTER TRAWLER WISCONSIN.

ween knot centers) cod end was used on a Standard $1\frac{1}{2}$ Iceland trawl with a of $5\frac{1}{2}$-inch (between knot centers) mesh throughout. Both cod ends were concted of 50-yard, 4-thread, double twine. The 5-inch belly used on the No. 41 l was constructed of 75-yard, 4-thread, single twine; the $5\frac{1}{2}$-inch belly used ne Iceland trawl was constructed of 60-yard, 4-thread, single twine.

The cod ends were covered with a bag of $1\frac{1}{2}$-inch, 24-thread cotton shrimp net- to catch the escaped fish. Results from the previous cruises had shown that

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: WEIGHT OF TWINE IS EXPRESSED IN NUMBER OF YARDS PER POUND.

the cover did not have any effect on the selectivity of the cod end under conditions.

The meshes of the cod ends and bellies were measured frequently thro the course of the experiments to determine any changes in size of mesh (f Measurements were made flat wedge-shaped gaug serted under a pressur pounds into the meshes net while wet and afte according to the recom tions of the Internati Commission for the Nor Atlantic Fisheries.

The catches from end and cover of each tow were kept entirely rate and all haddock fr and cod end were measu Certain phases of the tions at sea are shown ures 3 to 6.

RESULTS

EFFECT OF USE ON SIZE: Of great import applying the results o iments on the selectiv of meshes is knowledge relation between mesh new nets and used nets of importance is the e of continued use on me The results of the Mic experiments showed tha size increases with co use and that the amour crease depends on the the catches. It was a that the after part of end stretched more tha forward part.

FIG. 2 - IN ORDER TO MEASURE THE MESHES OF THE EXPERIMENTAL COD END IT WAS NECESSARY TO CRAWL INSIDE THE COVER.

Table 1 - Sizes of Mesh (Inside Measurements) in a $5\frac{7}{8}$-Inch (Between Knot
Cod End after Use.

When Measured	Part of Cod End Measured QUARTER 1st (after)	2nd	3rd	4th (forward)	Approxi Average Entire C
After 1 tow	4-3/8	4-1/2	4-1/8	4-1/8	4-1/
After 10 tows	4-1/2	4-1/2	4-1/4	4-1/8	4-3/
After 22 tows	4-5/8	4-5/8	4-1/4	4-1/8	4-3/
After 43 tows	4-3/4	4-3/4	4-1/4	4-1/8	4-1/
After 57 tows	4-3/4	4-3/4	4-1/4	4-1/4	4-1/

imilar results were found for the cod ends tested on the Wisconsin cruise. results are summarized for the $5\frac{7}{8}$-inch cod end in table 1 and for the $6\frac{3}{8}$-

2- Sizes of Mesh (Inside Measurements) in a $6\frac{3}{8}$-Inch (Between Knot Centers) Cod End after Use.

When easured	Part of Cod End Measured QUARTER 1st (after)	2nd	3rd	4th (forward)	Approximate Average for Entire Cod End
2 tows	4-7/8	4-3/4	4-3/4	4-5/8	4-3/4
6 tows	4-7/8	4-3/4	4-3/4	4-5/8	4-3/4
9 tows	5-1/8	4-3/4	4-5/8	4-3/4	4-3/4

od end in table 2. The average inside measurement of the $5\frac{7}{8}$-inch mesh in- d rather regularly from $4\frac{1}{4}$ to $4\frac{1}{2}$ inches throughout the cruise. After the ow, the after meshes averaged $\frac{1}{2}$ inch larger than the forward meshes. The t catch during these 57 tows was about 4,300 pounds. The $6\frac{3}{8}$-inch cod end ed only a few times and consequently showed very little change in average ize. The inside dimensions of the after quarter increased $\frac{1}{4}$ inch after the two tows and there was only $\frac{3}{8}$ inch difference between the after and forward rs of the cod end after 9 tows. The largest catch taken was 2,000 pounds.

he 5-inch belly used on the No. 41 trawl measured $4\frac{5}{8}$ inches (inside dimen- after 43 tows. The $5\frac{1}{2}$-inch belly on the Iceland trawl was used for only

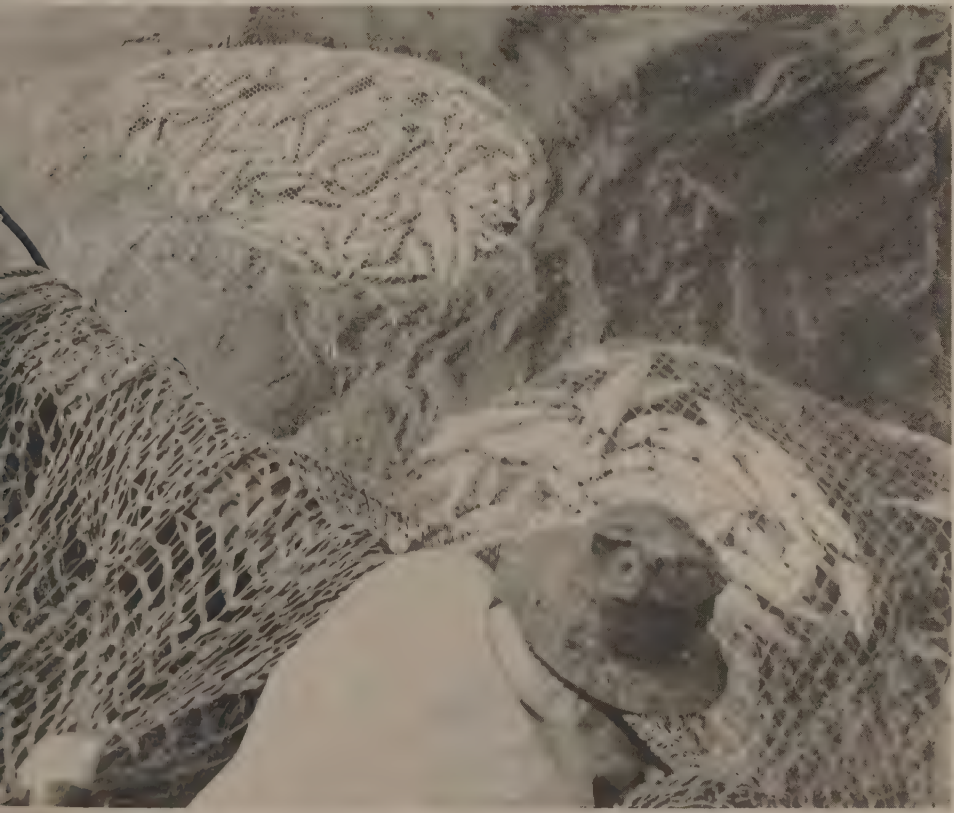

FIG. 3 - A FULL COVER FLOATS ALONGSIDE THE VESSEL.

9 tows, when it also measured $4\frac{5}{8}$ inches inside. These nine tows were no
cient usage to stretch the belly meshes fully. Another factor tending t
ize the internal mesh
the two bellies was t
of heavier twine in t
inch belly (60 yard,
Heavier twine with co
larger knots reduces
ternal size in relati
the knot center size.

ESCAPE OF FISH T
THE MESH: The select
sizes of haddock with
inch cod end is shown
3. The results prese
for eight tows in whi
total of 4,117 haddoc
cm. (8 inches) and la
taken. Almost all fi
0.6 pounds escaped, w
most all over 1.6 pou
retained in the cod e
50-percent selection
came at about 37.3 cm
inches). Haddock of
length weigh about 1

The selective ac
the $6\frac{3}{8}$-inch mesh is s
table 4. A total of
fish over 20 cm. (8 i
were taken in six tow

FIG. 4 - THE COVER SWINGS ABOARD.

Table 3 - Selectivity of the $4\frac{1}{2}$-Inch (Inside Dimensions) Cod End

Gutted Weight	Length1/	Fish in Cover	Fish in Cod End	Total Caught	Percentage Retained in Cod End
Lbs.	Cm.2/	No.	No.	No.	%
.2	21	1	-	1	0.0
.3	24	8	-	8	0.0
.5	27	59	2	61	3.3
.6	30	90	14	104	13.5
.8	33	218	73	291	25.1
1.0	36	363	355	718	49.4
1.3	39	382	649	1,031	62.9
1.6	42	144	686	830	82.6
2.0	45	35	413	448	92.2
2.3	48	5	294	299	98.3
2.8	51	-	182	182	100.0
3.2	54	-	87	87	100.0
3.8	57	-	34	34	100.0
4.3	60	-	9	9	100.0
5.0	63	-	4	4	100.0
5.6	66	-	5	5	100.0
6.4	69	-	4	4	100.0
7.2	72	-	1	1	100.0
-	-	1,305	2,812	4,117	-

1/ SIZE GROUPS BY 3-CM. INTERVALS. DUE TO THE METHOD OF RECORDING FISH LENGTHS TO THE LOWER FULL CENTIMETER (E.G. ALL LENGTHS FROM 21.0 CM. TO 21.9 CM. ARE RECORDED AS 21 CM.), AN ADJUSTMENT OF +0.5 CM. MUST BE MADE TO EACH LISTED GROUP LENGTH TO OBTAIN THE TRUE MID-POINT OF THE GROUP.
2/ 2.54 CM. EQUAL 1 INCH.

Table 4 - Selectivity of the $4\frac{3}{4}$-I
(Inside Dimensions) Cod End

Gutted Weight	Length1/	Fish in Cover	Fish in Cod End	Total Caught
Lbs.	Cm.2/	No.	No.	No.
.2	21	1	-	1
.3	24	10	-	10
.5	27	56	1	57
.6	30	115	8	123
.8	33	212	51	263
1.0	36	365	135	500
1.3	39	348	308	656
1.6	42	119	302	421
2.0	45	34	203	237
2.3	48	4	146	150
2.8	51	1	91	92
3.2	54	-	64	64
3.8	57	-	27	27
4.3	60	-	19	19
5.0	63	-	6	6
5.6	66	-	6	6
-		1,265	1,367	2,632

1/ SIZE GROUPS BY 3-CM. INTERVALS. DUE TO TH
RECORDING FISH LENGTHS TO THE LOWER FULL
(E.G. ALL LENGTHS FROM 21.0 CM. TO 21.9 C
CORDED AS 21 CM.), AN ADJUSTMENT OF +0.5
MADE TO EACH LISTED GROUP LENGTH TO OBTAI
MID-POINT OF THE GROUP.
2/ 2.54 CM. EQUAL 1 INCH.

t practically all fish under 0.8 pounds escaped while almost all over 2.0 were retained. This cod end had a 50-percent selection point at 40.0 cm. nches) of 1.4 pounds.

FIG. 5 - DRESSING DOWN THE CATCH.

e 50-percent selection points for the mesh sizes tested on both the Michi- Wisconsin trips are shown in figure 7. All four points line up quite well ch other and fit well to the theoretical line developed by Beverton and With such consistency in results one can predict with confidence the selection of cod-end meshes of other sizes.

e fact that the results with the Iceland trawl conform so well with those No. 41 trawls indicates that the type of gear has little effect on the se- action of the meshes.

SUMMARY AND CONCLUSIONS

1. Variations in the inside dimensions of two sizes of cod-end meshes we studied and found to agree with results of our previous experiments.

FIG. 6 - MENDING THE GEAR.

2. The selective actions of cod ends of $5\frac{7}{8}$-inch and $6\frac{3}{8}$-inch mesh were de mined and found to be consistent with that of the other sizes tested previou

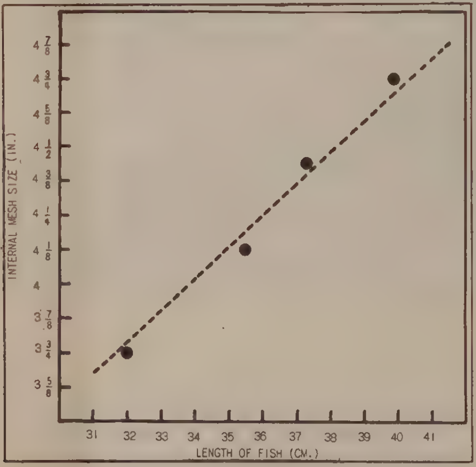

FIG. 7 - THE 50-PERCENT SELECTION POINT FOR EACH MESH SIZE (TO THE NEAREST $\frac{1}{16}$ INCH) TESTED ON THE MICHIGAN AND WISCONSIN. THE DOTTED LINE IS THE THEORETICAL RELATIONSHIP BETWEEN MESH SIZE AND 50-PERCENT SELECTION DEVELOPED BY BEVERTON AND HOLT.

3. A cod end of $5\frac{7}{8}$-inch mesh (mea between knot centers, new) constructe 50-yard, 4-thread, double-manila twin after use and when wet, have an avera inside mesh dimension of $4\frac{1}{2}$ inches pr it is used for 20 or more tows in nor fishing operations during which moder heavy catches of fish are taken.

4. Such a mesh would allow most haddock now discarded at sea to escap would retain most of the marketable-s haddock.

ACKNOWLEDGMENT

The cooperation of the New Engla fishing industry is gratefully acknowl We are again especially grateful to M Larson for the use of the Wisconsin a Captain John Stimberis and the entire for offering their fullest cooperatio Captain Westerbeke of the Westerbeke ing Gear Company, Inc. of Boston again assisted in the design and preparatio the special gear used in these experiments.

The following assistants participated in the collection and analysis of data: Sterling L. Cogswell, Robert R. Marak, and James W. McKee.

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Yearbook of Agriculture

nsects and
Vildlife

sects and the
ower Vertebrates

ver B. Cope

nsects are so diverse in structure
habit and so widely distributed
they come into close contact with
other groups of living things, ex-
the organisms that inhabit the
Through the contacts they have
ome involved in a variety of plant
animal relationships that bear all
rees of complexity and dependency.
m one-celled protozoan to man,
rly every animal group has come
levelop associations of one kind or
ther with the insects in the air, on
ground, or in fresh water. Some
ciations are quite casual. Others
so fixed that the existence of the
ct or its neighbor would be gravely
eatened by the removal of the other
nber.

he cold-blooded vertebrates—the
es, amphibians, and reptiles—also
e diversified habits. Aquatic, semi-
atic, subterraneous, terrestrial, and
oreal habitats put them close to
ny insect forms. Many specific rela-
ships between the two animal
ups have arisen through the ages.
haps no other classes can better
strate the interrelationships be-
en the insects and their neighbors
ature. It is also appropriate to con-
r the important economic implica-
s of these associations of the lower
tebrates, especially the fishes.

The cold-blooded vertebrate animals depend on insects for their sustenance in varying degrees. Sometimes, as with the turtles, practically no insect material enters the diet. On the other hand, large groups of fishes could hardly exist without the benefit of abundant insect forage to sustain them. Between these extremes are vertebrate animals—toads, small snakes, lizards—which although usually not in the habit of eating insects to the exclusion of other kinds of foods, ingest them in great numbers when they are readily available.

Studies by E. M. Uhler, C. Cottam, and T. E. Clarke on Virginia snakes revealed that almost all of 15 species examined had insects in their stomachs. Large insects, such as grasshoppers, cicadas, and caterpillars, were most frequently taken. Smaller forms, such as ants and small beetles, also were found in abundance. Insect remains represented the total contents in some stomachs. In others less than 50 percent of the food was of insect origin. Only a few of the smaller species of snakes, such as green snakes, ground snakes, and ring-necked snakes, are essentially insect eaters; insects contribute moderately to the diets of other species of snakes.

Lizards are the most decidedly insectivorous of the reptile group. Many are vegetarians. Large species specialize in relatively bulky prey, such as crabs and mice, but most small lizards—fitted with tongues adapted for capturing insects by lapping them up or by striking at them heavily—subsist chiefly on insects. G. F. Knowlton found that beetles, ants, leafhoppers, and other terrestrial insects are staple items in many lizard diets. Red-backed alligator lizards from Santa Rosa Island in California had little else but insects in the digestive tracts. Eighty percent of the stomach contents were darkling beetles. Larder beetles, ground beetles, stink bugs, and plantlice also were present.

Amphibians—the frogs, toads, and salamanders—because of their aquatic or semiaquatic habits, come into contact mostly with swimming or flying insects, although adult amphibians frequently seek crawling insects. Swimming or flying insects are readily taken as food by amphibians and in considerable quantities. Salamanders are not highly insectivorous but eat insects readily when they are available. In studies on the tiger salamander, D. S. Farner found that 74 percent of the stomachs examined had terrestrial arthropods, including ants, beetles, and flies. Thirty-seven percent of the stomachs contained aquatic beetles, flies, and caddisflies. Others have found mayflies, caddisfly larvae, and caterpillars in the food of salamanders.

Frogs are of minor importance as insect feeders, although certain species take insects in abundance. E. W. Jameson, Jr., in studying the western cricket frog, found beetles present as 55 percent of the total food volume, spiders as 24 percent, midge larvae and fly adults as 12 percent, and water boatmen as 7 percent. W. J. Hamilton, Jr., pointed out that the importance of insects in the diet of one species of frog varies with time and place. In summer and fall, when aquatic environments are usually restricted in area, grasshoppers become more important than in the spring. In both young and old frogs, beetles, flies, grasshoppers, and caterpillars were present as 60 percent of the bulk of the stomachs studied.

Toads are more dependent on the insects for nutrition than are other amphibians. The true toads, while omnivorous, taking only living or moving food and endowed with an extremely rapid digestive apparatus, consume large amounts of insect material. A. H. Kirkland determined tha percent of the food taken by throughout a season was of insect gin, authenticating the reputatio this toad for having a high econ value as a natural suppressor of i populations. H. J. Pack pointed that a large population of *Bufo w housii* in Utah in August 1921, feeding exclusively on sugar-beet worms. Each small toad had 24 t worms in its stomach. There was a centration of toads in the area, they were eating webworms to th clusion of their normal diet, a l that contributed greatly to the co of the undesirable insects. The sp foot toad, in its immature stages, active feeder on aquatic insects, ticularly the larvae and pupa mosquitoes.

The relationships between and insects as predator and pre much better known and unders than are those of other cold-blo vertebrates. Fish living in the o do not utilize insects as primary ponents of their diets, because in are so poorly represented in the Anadromous fish, which live in water during portions of their cycles, depend almost wholly or sect organisms during the fresh-w phase. There are fish, also, whic habit brackish water, gleaning bers of insects, among other organ in their search for food. It is in the fresh-water haunts, however, tha ultimate in the use of insects as food is attained and the debt of f water fish to the insects become vious. Both herbivorous and car rous insects, either aquatic or te trial, are utilized.

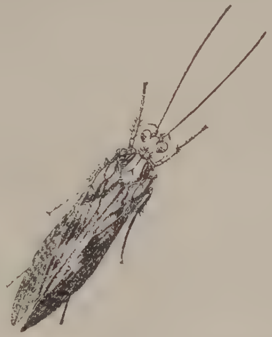
The relationships between a p lation of insects and a particular p lation of adult fish can be direct c direct. The fish may capture an a tic insect in the water of the strea lake or on the bottom. A flying i whose habits are terrestrial ma snatched from the air or water sur Herbivorous insects, such as midg

, may be devoured by carnivorous ms, like stonefly nymphs, which in n may be eaten by fish in streams. ects may contribute to the diet of a ge fish by falling prey to a small fish, ich is in turn captured by a larger . Aquatic insects may be utilized by tain fish during the first part of the 's development, before dietary its are changed. For example, the gemouthed black bass ingests quan- es of insects until it attains a length a few inches. After that time, small replace insects as the dominant n in the bass diet. All these possi- ties are everyday occurrences in the amics of food utilization.

STREAM HABITATS used extensively fish usually have a variety and ındance of aquatic insects. Streams ısidered suitable for trout and small- uthed black bass have a good bal- e of pools and riffles. The bottom ography, aside from providing rest- and feeding areas and incubation s for the fish, makes for the support a diversity of aquatic insects. Trout most streams subsist principally on se, whereas terrestrial insects that onto the water usually form the ond biggest portion of the diet.

The aquatic forms are associated h particular types of stream bottom. riffles, where shallow water flows idly over gravel bottoms, insects h high oxygen requirements dwell— early stages of stoneflies, mayflies, ldisflies, beetles, true flies, and other ds. In most streams, riffles carry nyfold the amount of insect life that resent in pools. Pools, however, pro- le numbers of fly larvae and mayfly nphs as fish food, and serve as tem- ary repositories for terrestrial in- ts that have fallen onto the water.

The insect types that dominate in mach samples in stream fish usually low a pattern, which varies only derately according to the physical ure of the stream bottom and the mical nature of the water. Mayflies caddisflies usually occupy the most minent place in the diet of trout and salmon. Of lesser importance are true flies, stoneflies, beetles, bugs, and nymphs of dragonflies and damselflies.



Phryganea vestita, a caddisfly.

Often trout will engorge great quantities of one particular kind of insect, no matter to what group it may belong, presumably because that insect is readily available as food. This occurrence is common at times of adult mayfly emergence, for instance. Adult smallmouthed bass have been found to prefer mayfly nymphs to other insects, with dragonflies, damselfles, and true bugs as second choices. Stoneflies, caddisflies, and beetles are used to some extent, and moths and nerve-winged species are taken in limited numbers. Fingerling smallmouthed bass prefer small organisms and ingest midge larvae almost exclusively in June from both riffles and pools. In July great quantities of mayfly nymphs are consumed, but fly larvae continue to serve as the chief food type. In August mayfly nymphs become the dominant item.

FISHES OF SPORT or commercial importance in streams are not alone in their dependence upon insects for their food. The rough or trash fish—those that are not usually sought for their food or sport value and that often prey on or compete with valuable fish—take their share of insect material as food. Insects devoured by small rough fish, however, may ultimately help form flesh on a prized game fish; for example, a mayfly taken by a young sucker, which migrates downstream to a lake, falls prey to a walleye. Stomach contents of several members of the minnow family, which serve in nature as important forage for game fish, usually include insect matter as a primary component, where it is available. Some members of this family are dace, minnows, roaches, chubs, blackfish, squawfish, and shiners. A few other nongame fish dependent upon insects to varying degrees are suckers, sticklebacks, topminnows, and sculpins.

Lake-dwelling fish utilize insects and bugs almost as much as do fish that inhabit streams. Forage fish assume immense importance in the diets of lake fish when adult size is reached, but before the advent of adulthood smaller organisms must form the bulk of the intake. Insects of various kinds fit into suitable size categories in this regard, and, where ecological conditions will support large enough insect populations, lake fish of the smaller sizes often are sustained almost completely by the insect fauna.

Trout in lakes and ponds vary their diets from lake to lake and from season to season. While garnishing their food with assortments of crustaceans, mollusks, and spiders, trout are generally consistent in their use of two staple items—insects and smaller fish. Various studies on lake foods have shown many proportions between these two foods. J. W. and F. A. Leonard found 8- to 12-inch rainbow trout using aquatic insects as 40 percent of their diet and fish as 30 percent. Rainbow trout 12 to 22 inches long from the same lake had aquatic insects as 18 percent of their food and fish as 48 percent. Mackinaw trout from the same lake and during the same years contained 11 percent aquatic insects by volume and 83 percent fish. A. S. Hazzard and M. J. Madsen found that 5- to 23-inch cutthroat trout from Glacier Park lakes contained 54 percent insect food. The same species, 7 to 21 inches in length, from lakes of Teton Park, had 12 percent insect
and 68 percent fish in the stomac

Other game fish in lakes and p
use insects in substantial numbers,
as with the trouts, smaller fish ha
greater dependence on them tha
fish of greater size. Bluegills at t
may have insects as 90 percent of
stomach contents. Other spiny-r
fishes, such as black crappie, ye
bullhead, yellow perch, pumpkins
long-eared sunfish, rock bass,
largemouthed bass, have been foun
take insect food in large amou
Some other species that consume
sects in ponds, lakes, and reservoir
sturgeon, suckers, whitefish, and c

In streams and lakes, eaten by pr
sport fish and lowly trash fish, yo
or old, bottom feeders or plan
eaters, insects enter into the nou
ment of most fresh-water and a
romous fish. Diets vary from plac
place and from time to time, bu
most any given population of fis
fresh water, if deprived of insect
sustenance, would be forced to a
new feeding habits or starve.

The most commonly recog
relationship between insects and
lower vertebrates, that of prey
predator, is frequently reversed in
ture. Some insects make a habi
viciously attacking, killing, and f
ing upon fish and their vertebrate
tives. The most prominent lim
factor in this type of behavior is
of size, but even overwhelming ad
tages in this regard are commonly
regarded by some types of insect p
ators that are especially well equi
for the attack. A pointed and long
boscis, as wielded by a toe-biter (
coridae), or a set of robust and s
mandibles of the caliber flourishe
many beetle larvae can be very e
tive in subduing victims many t
the size of the attacking insect.

Among the best known of the
eating insects are certain aquatic
tles, some of whose adults habit
attack fish and others of which are
daceous as larvae. The carnivo

ng beetles probably rate foremost,
larvae and adults regularly prey-
upon fish, even when several times
r size.

wo groups, *Dytiscus* and *Cybister,*
dreaded by pondfish culturists.
se beetles take fish of several spe-
under normal conditions and rep-
nt a special threat to newly
hed fish. Under conditions where
ral predators cannot keep the bee-
in check, fish fry are sometimes
d about as often as they appear.
er scavenger beetle larvae habitu-
kill small fish, both in nature and
fish-cultural practices that bring
e numbers of fish and beetles into
e quarters. These beetles generally
omnivorous, but some species of
rous have the habit of taking fish
the diet. In fishponds, *Hydrous*
ae have reduced populations of
alo fish and carp. Fish remains
e been found in the stomachs of 12
of 50 larvae examined in a series
tudies.

ne other noteworthy beetle family
hat of the whirligig beetles. Both
ae and adults commonly devour
under natural conditions, and fish
urists attempt to keep their ponds
from these predators. The genus
eutes has species which, even in
presence of an abundance of other
d, will choose to swarm about a fish
il it succumbs.

HE TRUE WATER BUGS hold a high
k among the insects that are de-
ctive to fish. They are strong swim-
s and fliers, often grow large, and
fitted wth formidable piercing and
ing mouth parts. The giant water
s are so strongly associated with
predation that they are often called
killers. Fish of many species are
rcome and fed upon in ponds and
er types of water, and large speci-
ns of giant water bugs, 4 inches or
e in length, often assault foot-long
t. The vicious habits of two of
se bugs, *Belostoma* and *Lethocerus,*
ount for the mortality of numerous
of many species in nature. The back swimmers are renowned for their attacks upon young fish. Their relatives, the toe-biters, often overpower small fish.

The dragonflies and damselflies have been incriminated as destroyers of small fish. The nymphs of the larger kinds, especially *Aeschna* and *Anax,* are notorious; early fish culturists were ever on the alert for the presence of large dragonfly nymphs in their fishponds. All such nymphs are not guilty of attacking fish, and, indeed, the idea that even the most voracious habitually devour fish has been largely refuted. That fish populations ever suffer materially from their ravages is yet to be established conclusively.

Certain immature caddisflies will attack fish and kill them. Larvae of the seine-making caddisflies have been considered a minor menace in trout and salmon hatcheries. These net-spinning, predaceous larvae enter rearing troughs with the water supply and entangle and feed upon trout and salmon fry. Not until the fish have attained a size great enough to prevent entanglement do they attain relief from the larvae. The larvae habitually attack tiny fish in nature, as well. It is not uncommon, on digging into a salmon nest, to come upon one of these larvae in the act of grasping a newly hatched fry, which has just begun its ascent through the gravel to the flowing stream above. All in all, the significant reduction of fish populations in nature or in hatcheries through the action of insects is not frequent, and, when it occurs, is almost always done by water bugs or beetles.

The immature stages of frogs and salamanders are vulnerable to the attacks of some of the larger predaceous aquatic insects. Beetles and bugs will assault larvae and tadpoles under natural conditions, and may exert a degree of control over an amphibian population.

AN EXAMPLE of successful biological control in the field is the suppression of obnoxious aquatic insects through the introduction of fish to waters in which insects breed. Mosquitoes have been controlled in their larval and pupal stages in tropical and subtropical areas by the method. Gnats whose immature stages are readily available to fish have also been brought under control through the planting of suitable fish in infested waters. A long history of difficulties and failures in trying to introduce fish for the purpose attests the fact that success is usually not attained without considerable thought and planning. When the right combination of fish and environment is discovered, however, the economic return of the effort may be extremely gratifying.

The practice of stocking mosquito-laden waters with appropriate fish for permanent control has become such an indispensable part of the well-rounded mosquito-abatement program in many tropical areas that specialists are retained just to raise and distribute the fish. The Rockefeller Foundation and the Brazilian Government, in developing an organization in Brazil for the fight against the yellow-fever mosquito, established a fish service for work in cities. The service maintains all the facilities necessary for the storage, transportation, and planting of fish, and has a staff to supervise their use. The service is set up on a businesslike, permanent basis and illustrates the importance attached to control through fish in that area. Many other programs in tropical regions hold fish to be of prime importance in the organization of control measures. In the United States, some States require that top-feeding fish be kept in all small reservoirs.

Two FAMILIES OF FISHES, well adapted for the purpose, have been extensively used for the control of mosquito larvae. One group, the top minnows, family Poeciliidae, is native to the New World in temperate and tropical climates. The popularity of certain top minnows as mosquito killers has led to their introduction into other lands; indeed, in the case of a minn
known as *Gambusia,* there is proba
no major region of the world to wh
these fish have not been carried
abatement purposes. In the Un
States, one species, *Gambusia aff*
has been used in California, Te
and in the Mississippi Valley; anot
species, *Gambusia holbrookii,* has b
stocked on the Atlantic coast, f
Virginia to Florida. Still other spe
have been used extensively for m
quito control in Central and Sc
America, the West Indies and
Mediterranean region, those know
Lebistes, "millions," *Mollienesia,* m
fish, *Poecilia,* and *Heterandria* hav
been most popular. Short life cy
abundance, small adult size suit
for penetrating vegetation, fecund
surface-feeding habits, and ease of
tribution make the fishes of this fa
readily usable for mosquito abatem

The other family of fishes fav
for mosquito-eating habits is tha
the killifishes, family Cyprinodonti
They are native to temperate
tropical regions. Like the top minn
the killifishes are endowed with bi
gies and life cycles that are ide
suited to depredations on mosquito
vae and pupae, and they have b
used both in their native waters
through introduction to remote a
In North America, the killifish *Fu*
lus has been encouraged in antim
quito practice on the salt marshe
the Atlantic coast. In Central
South America, another species, *R*
lus, has served admirably in abaten
work and is among the most wi
used predators in those regions.
the Mediterranean region, *Fund*
and still another, *Cyprinodon,* h
contributed toward control.

Some other families of fishes h
members that are effective in anti
val campaigns. In the minnow fan
Cyprinidae, the well-known gold
often does an excellent job of supp
ing mosquito larvae in garden p
and other artificial waters. The cat
Pygidium, has been a success in
native South America, and var

fishes have been used there in
ight against mosquitoes.

SECOND EXAMPLE of a fortunate
bination in biological control in-
es an amphibian. A long history
onomic loss to sugarcane in trop-
areas through the ravages of June
e larvae prompted an investiga-
into possibilities for control in
to Rico. The larvae had several
ral enemies, including lizards and
tree toads, but those predators
too small to exert significant con-
The importation of large, noc-
al toads to Puerto Rico was rec-
ended as a feasible action against
white grubs. Accordingly, adults
e giant Surinam toad (*Bufo mari-*
were brought to the island and
sed. The white grubs were readily
by the toad, and *Bufo* saved the
rcane holdings in Puerto Rico.
in 10 years, the grubs had become
on the island.

e success of *Bufo marinus* in
to Rico occasioned its introduc-
to other tropical places. An im-
ation into the Hawaiian Islands
aimed at control of another sugar-
pest, the oriental beetle, and the
is doing a good job of controlling
eetles.

nother toad that has been sug-
d for use in insect control is the
efoot toad, *Scaphiopus*. In this
the tadpole rather than the adult
attracted attention, because of its
tite and equipment for capturing
quito larvae. This tadpole has
ed its efficiency in ridding bor-
pits and other temporary ponds of
quito larvae, and has been sug-
d for similar activities in more
anent waters.

oads generally have a high value
xterminators of insects, especially
e Tropics. Indeed, in many places,
are maintained as substitutes for
ticides in suppressing garden pests.
their rapid digestive rates and
habit of choosing only living or
ing food, toads can consume enor-
s quantities of insects in a day.

Among the reptiles, lizards are obviously the best potential controllers of insect populations because of their natural habit of using insects in the diet. In the Tropics, they approach birds as insect destroyers. Lizards are not usually encouraged to the point of introducing them to insect-infested areas, but they are given free run of most houses in many tropical regions.

THE FISHERY BIOLOGIST has many field techniques for helping the welfare of fresh-water fish populations. Many of his management practices consist of rather drastic modifications of the physical environment of the fish for the purpose of improving spawning conditions, reducing mortality, or promoting growth. Many techniques are initiated expressly to increase fish growth through the increase of insects for food. That is done through predictable changes in the insect habitat and is calculated to provide aquatic conditions that will promote rapid and sustained development of the insect fauna. In effect, therefore, a good deal of management of fresh-water fish through environmental change becomes the management of aquatic insects.

Lake management has many possibilities. The employment of the various methods may only indirectly affect fish through bettering conditions for insect existence, but often the results are rapid.

Changing the temperature of a lake usually directly affects the insect fauna. Lakes may be warmed by increasing shoal area, resulting in the increase of fish food. The control of pollution is usually aimed directly toward improving chemical conditions for the fish themselves, but often renders aquatic insects more abundant. The regulation of the water level, primarily initiated for the benefit of spawning conditions or to prevent stranding of fish, frequently brings about stabilized conditions favorable for insect organisms used as foods. Providing shelter in the form of logs and brush gives fish a feeding place where aquatic organisms will become readily available for them. When the fishery manager retards wave action in lakes, he often makes insect production greater by reducing silt in the water, thereby increasing the penetration of light. The management of competitors in a lake definitely involves the insect fauna; where the insects are competed for as food, the problem becomes one of making the best use of the insect material on hand. The regulation of plant growth in a lake directly concerns the insect fauna present, and represents a step in the promotion of food chains and anchorage for aquatic insects. The increase of natural food in lakes is thus brought about in various ways by the fishery manager—to repeat, by chemically fertilizing the water, by directly controlling turbidity and temperature, by creating widespread shoal areas, and by providing shelter for insect organisms.

Streams are susceptible to the same management techniques as lakes. Certain other mechanical changes often are used in stream management to achieve improved hydraulic conditions for fish and a better environment for the insects that fish eat. Chemical fertilization for the acceleration of food chains, control of pollution, regulation of competitors, promotion of plant growth, and provision of shelter can all be used to alter the stream environment in favor of its fish inhabitants. Somewhere along the way the aquatic insects are usually affected favorably and are in turn consumed by fish.

Building dams for the benefit of fish is a common stream-improvement practice. The check-dam, a low structure placed at the outlet of a mountain lake, checks excessive spring flows in the stream below, and maintains summer flows. The checking of spring runoff prevents the washing away of insect life, while the sustained summer flows provide a greater stream-bottom surface for the production of bottom insects. High dams, which impound deeper waters, sometimes serve as regulators of downstream water temperature. The high winter-water tempe
tures below such dams encourage
sects to grow and multiply so that fo
conditions become favorable for fi

Placing boulders or other obstr
tions in streams is another mana
ment tool that improves conditions
aquatic insects. Such obstructi
change water-flow patterns by cre
ing new areas of deep, quiet water t
will support a new insect fauna. In f
water, the obstructions usually al
ecological conditions in favor of
fish and their chief food, the aqua
insects. Another structure, the defl
tor, is placed in running streams
order to change flow characterist
and form pools. Made of immova
logs or rocks, deflectors in strea
often bring about marked impro
ment of productivity of stream life

Even more drastic physical chan
may be brought about in streams
changing the stream course. Usua
that is done with a specific purpose
mind, but it generally results in
stream section that is better suited
fish life and food production. Wh
new riffles appear through this mea
food production increases according

Biologists concerned with fish a
other cold-blooded vertebrates cann
avoid the implications of field tre
ments with almost any of the new
more toxic insecticides. Fishery bio
gists particularly have had to be
the alert, since bodies of water ha
been the focal point for treatme
against many insect pests. They m
be aware of the effects of insectici
on the fish themselves through dir
poisoning. They have also maintain
interest in the effects of new insec
cides on aquatic insects eaten by fi
Indirect damage to fish can co
about in two ways—through the co
sumption by fish of insects that a
saturated with a toxicant and by d
priving the fish of the bulk of th
food, if the food organisms have be
destroyed by insecticides.

Large-scale insecticide treatments
the field are directed against mosq

Many of the ecological situations
ented by mosquito larvae and
e fortunately are not important
sh habitat. Mosquitoes generally
e quiet, shallow waters, often of
nporary nature and not accessible
sh. In such places, the danger to
s least when well-controlled meth-
of toxicant application are used.
ever, airplane spraying against
uito larvae may be hazardous to
in waters adjacent to the area be-
treated. In the San Joaquin Val-
f California in 1950 toxaphene in
sene solution, with an emulsifier,
deposited by airplane at rates up
pound per acre of water, which
much in excess of the usual 0.2–0.3
d per acre normally used. Biolo-
of the California Division of Fish
Game found numbers of black
, sunfish, and catfish dead as a
t of the insecticide treatment.
instances are rare, however, and
gratifying that the modern mos-
o-abatement supervisor is aware
he ecological situation as he uses
ticides in the field.

ontrol of forest insects often en-
the wide dispersal of potent toxi-
s over forest areas through which
t streams flow. In heavily forested
es under airplane treatment, it be-
es impractical to treat the woody
s without covering the streams.
problem is one of choosing the
l insecticide in such strength that
forest insect pests will be destroyed,
le harm to fish and fish food is kept
minimum.

he control of black fly larvae and
ae in running streams has been at-
pted by chemical methods. The
rd then to other aquatic organ-
is very obvious. Streams inhabited
lack flies are almost always swiftly
ing and usually contain popula-
s of trout or other prized fish, such
salmon, smallmouthed bass, or
l. Also in need of protection are
various minnows and other forage
and the bottom-insect fauna so
ortant as fish food. When chem-
s are poured directly into the
stream for action against the black flies, the problem again is principally one of choosing the most suitable insecticide—the one that will yield effective control while inflicting a minimum of damage on useful aquatic organisms.

Federal and State agencies have experimented with the new toxicants considered to be the most promising for field campaigns. Insecticides have been tested against many kinds of fishes and their foods, and toxicity thresholds have been established for various aquatic environments in the laboratory and in the field. Different formulations have been tested and different methods of insecticide dispersal have been tried, so that field biologists are now armed with facts that will guide them in the safe use of insecticides outdoors. Cooperative projects, in which entomologists and fishery biologists have worked together in the field on these problems, have been successful.

The new chemicals about which we know most in relation to their fish-killing properties are DDT, benzene hexachloride, chlordane, as well as toxaphene, TDE, methoxychlor, parathion, and tetraethyl pyrophosphate. Various formulations have been tested. The most popular mixtures have been xylene-triton emulsion, kerosene solution, fuel-oil solution, and acetone solution.

The choice of a field insecticide entails several considerations—cost, ease of handling, safety to humans, effectiveness in destroying the pest, and safety to wildlife. On those bases, DDT seems to be one of our safest all-around insecticides. TDE has shown promise against certain insect pests and is only mildly toxic to fish. Chlordane, methoxychlor, and benzene hexachloride have been used experimentally against some kinds of fish and might be all right to use under carefully controlled conditions. Toxaphene is very toxic to fish, and should be used only with extreme caution. The type of formulation can often affect the toxicity of these chlorinated hydrocarbons. In most instances xylene-triton emulsions of these toxicants are most toxic to fish, oil solutions are intermediate, and acetone solutions exhibit the least potency.

Fish are not alone among the cold-blooded vertebrates in their vulnerability to insecticides. Wartime tests by E. S. Herald in Florida showed that DDT-kerosene solutions, as sprayed routinely from aircraft, killed green water snakes, banded water snakes, coachwhips, black snakes, pine snakes, and king snakes, and one of the four cottonmouth moccasins that were exposed. Typical DDT tremors were observed in frogs and toads, although they appeared to be moderately resistant to its action.

As we accumulate new facts concerning the tolerances of fish and other cold-blooded vertebrates to the newer insecticides, we shall arrive at a better understanding of the possibilities for safe field treatments. The complex aquatic environment binds all of its members so closely that careful m agement becomes strictly necessar the desirable components are to be p petuated.

In the give-and-take struggle which all animals are engaged, i obvious that many kinds of animals decidedly dependent upon the legged arthropods; certainly the c blooded vertebrates would have a m difficult time in discovering a suit substitute for the insect link in the f chains leading to their subsistence

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EEKDAY ANGLING PRESSURE IN THE SACRAMENTO-SAN JOAQUIN DELTA, 1948 AND 1949[1]

By OLIVER B. COPE and LEO F. ERKKILA
U. S. Fish and Wildlife Service, Stanford, California

INTRODUCTION

The Sacramento-San Joaquin Delta in California is one of the most opular and productive large sportfishing areas in the State. The delta an intricate network of waterways separated by low islands that are otected by levees, and its waters aggregate about 500 miles of channels various sizes. The widest channel is more than 4,000 feet wide, but me of the waterways measure less than 100 feet from bank to bank. tuated only an hour's drive from the large urban areas of the San rancisco Bay region, well supplied with highways and access roads, nd with many bait shops, boat liveries, and other facilities for the ngler, the delta area has developed into a sport fishermen's recreation round that is probably unequaled in popularity by any other area of s size in California.

Sport fishing in the delta area is directed toward several kinds of rized game fishes, some of which also enter the commercial fishery in e same waters. Foremost among the fishes sought by sport anglers the delta is the striped bass (*Roccus saxatilis*), whose adults utilize ese waters for feeding and spawning, and whose immature stages ndergo much of their development here. The white catfish (*Ictalurus tus*) is greatly sought in delta waters, and is abundant throughout uch of the maze of channels making up the area. The brown bullhead *Ameiurus nebulosus*) often appears in delta catches, and, on rare occa- ons, the channel catfish (*Ictalurus lacustris*) is taken. A small sport shery for king salmon (*Oncorhynchus tshawytscha*) is found on the utskirts of the delta (Sacramento and San Joaquin Rivers), although is fishery is of minor importance compared to the salmon fisheries ccurring above the delta. Largemouth black bass (*Micropterus sal- oides*), bluegill (*Lepomis macrochirus*), green sunfish (*Lepomis cyanel- s*), and black crappie (*Pomoxis nigromaculatus*) are numerous in parts the delta region, and many anglers seek them in their fishing efforts. ith such a variety of resident and anadromous fishes available in the me waters, it is understandable that the Sacramento-San Joaquin delta hould be so popular among sport fishermen in Central California.

The present paper deals with the amount of fishing effort observed ver an extended period in various channels of the delta. Calhoun (1949) ade a thorough treatment of the party boat fishery for striped bass in e delta from 1938 to 1948. His summary of boat days, angler days, and

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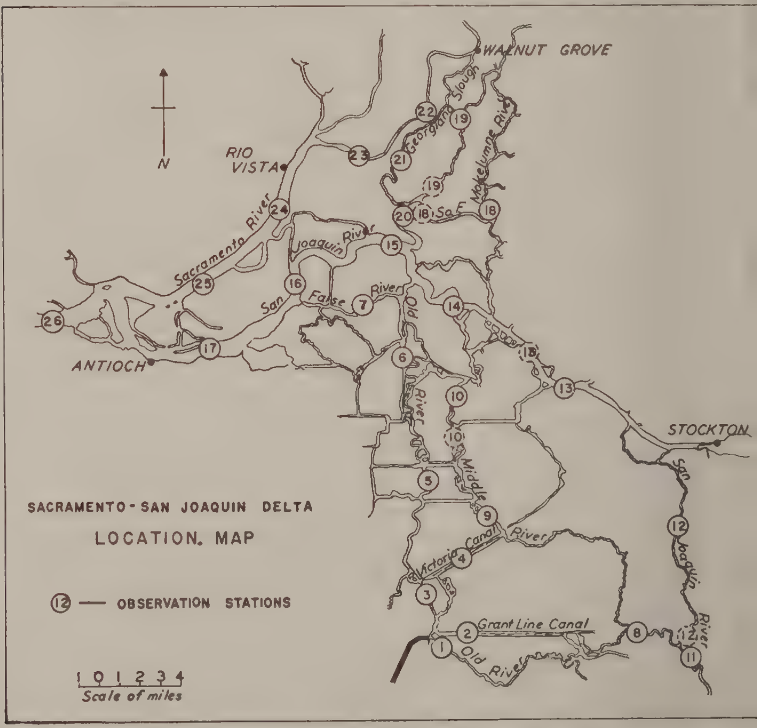
numbers of striped bass landed showed the enormous amount of effor expended and the large numbers of striped bass taken from party boat alone. Calhoun (1950), in his discussion of angling catches throughou the State, provided substantial evidence of the popularity of the delt area and of the success of anglers in delta waters, particularly with reference to striped bass and catfish. Calhoun (1951) compared anglin catches for California in 1948 and 1949 for several species of fish, including those species that are most popular in the delta. Although total catc estimates, mean catch estimates, and numbers of successful anglers wer slightly greater in 1949 than in 1948, the differences with respect t striped bass were not statistically significant. Differences in mean catche of catfish and black bass were statistically different, indicating decrease in success from 1948 to 1949. The present paper does not deal with catche nor with species, but provides some comparative figures on fishing effor from place to place in delta waters. A comparison is made also of fishin effort in the delta in 1948 and 1949. Trends in effort from month to month and from weekday to weekday, are described.

The U. S. Fish and Wildlife Service was engaged in a biological surve of delta waters during 1948 and 1949. In the course of these investigations, routine collections of physical and biological data were made b


N
WALNUT GROVE
RIO VISTA
Georgiana Slough
Mokelumne Riv
Sacramento River
San Joaquin River
S.a.F.
False River
Old River
Middle River
Victoria Canal
Grant Line Canal
Old River
San Joaquin River
ANTIOCH
STOCKTON
SACRAMENTO - SAN JOAQUIN DELTA
LOCATION. MAP
12 — OBSERVATION STATIONS
1 0 1 2 3 4
Scale of miles
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
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25
26

FIGURE 1. Locations of observation stations in the Sacramento-San Joaquin Delta. 1948 and 194 stations are shown by number in solid circles. Stations relocated in 1949 are shown in broken circles

oat at sampling stations distributed throughout most of the delta area, rom Sacramento River below Walnut Grove on the north, to San Joaquin iver below Mossdale on the south, and to the mouths of Sacramento and an Joaquin Rivers on the west. Twenty-five such stations were maintained in 1948.

In 1949, 20 of the 25 1948 stations were continued, and an additional ite, Station No. 26, was added in the month of May. New locations were et up on the same streams to replace the five 1948 stations that were iscontinued. The following list indicates the locations of the collecting tations visited (see also Figure 1) and their number designations.

tation No.	*Location*
1	Old River, Livermore Yacht Club upstream two miles.
2	Grant Line Canal, Grant Line Bridge to Old River.
3	Coney Island Cut, entire length.
4	Victoria Canal, entire length.
5	Old River, Woodward Canal to Santa Fe Railroad Bridge.
6	Holland Cut, entire length.
7	False River, overhead cables to Fishermen's Cut.
8	Middle River, San Joaquin River to Salmon Slough.
9	Middle River, Borden Highway Bridge to North Victoria Canal.
10 (1948)	Middle River, Santa Fe Railroad Bridge to Empire Cut.
10 (1949)	Middle River, Empire Cut to Connection Slough.
11	San Joaquin River, ½ mile below Southern Pacific Railroad Bridge, Mossdale, to Middle River.
12 (1948)	San Joaquin River, ½ mile below bifurcation of Middle River for two miles downstream.
12 (1949)	San Joaquin River, Brandt Bridge to Borden Highway Bridge.
13 (1948)	San Joaquin River, Navigation Light No. 21 to Light No. 17.
13 (1949)	San Joaquin River, Turner Cut upstream to Navigation Light No. 35.
14	Venice and Mandeville Cuts, Navigation Light No. 5 to Light No. 2.
15	San Joaquin River, Mouth of Mokelumne River to Seven Mile Slough.
16	San Joaquin River, Three Mile Slough to False River.
17	San Joaquin River, Blind Point to Mayberry Cut.
18 (1948)	South Fork Mokelumne River, North Fork to Terminous.
18 (1949)	South Fork Mokelumne River, Terminous to Sycamore Slough.
19 (1948)	North Fork Mokelumne River, mouth of South Fork upstream two miles.
19 (1949)	North Fork Mokelumne River, five miles above South Fork upstream two miles.
20	Mokelumne River, Georgiana Slough to Jackson's Harbor.
21	Georgiana Slough, Tyler Island Bridge to mouth of Slough.
22	Sacramento River, Pratt-Low Preserving Company Cannery to Isleton Highway Bridge.
23	Sacramento River, Isleton to Grand Island Sounding Board.
24	Sacramento River, west side of river, Rio Vista to Three Mile Slough.
25	Sacramento River, east side of river, Toland's Landing to Towers.
26 (1949)	Sacramento River, Bell-buoy No. 10 to Stake Point.

In 1948, each station was worked about once each week, on a weekday, rom April 9 to December 15. Under this regime, almost all stations were isited 18 or 19 times during the year. In 1949, each station was worked nce a week, Tuesday through Friday, from January 26 to September 21. his schedule covered each station, except No. 26, 32 or 33 times during he sampling season. Station 26 was visited 19 times in 1949. Although a ruly random sampling schedule, with regard to day of the week and our of the day for each station, was not followed, no station was visited lways on the same day of the week or at the same hour of the day.

Observations on the numbers of anglers were made each time the boat perated at a station. While the operation, consisting of a half-hour netow, was in progress, personnel equipped with field glasses kept records of the numbers of shore anglers and those in boats within the confines of the station. The lengths of stations varied from about one-half mile to two miles. The time for counting anglers on each station consisted of the half-hour duration of the tow plus a few minutes (up to 10 minutes) at the station before and after the actual towing.

ANGLING PATTERNS

In this report, angling has been divided into ''shore fishing'' and ''boat fishing.'' Shore anglers fished from the banks or from piers with casting equipment or drop lines. Boat fishermen used skiffs (usually with outboard motors), small inboard launches, larger party boats, and a few large pleasure cruisers up to 50 or 60 feet long. Boat fishermen used a greater variety of angling equipment than did shore fishermen. Some trolled with lures; others anchored and fished with baited casting gear. Bait fishing for striped bass with chunks and filets of sardine was the most widely observed method seen in this study. Juvenile striped bass and catfish are the principal fish sought during the summer months, and large striped bass are the chief sport fish in the delta from mid-September through May.

No breakdown of boat effort into launch and skiff fishing was made in 1948. Although such a breakdown was made in the field in 1949, the detailed information shown here in tabular and graphic form compares boat fishing in general with shore fishing. Some figures are presented for the 1949 season as a whole, showing relative numbers of launches and skiffs used in the observation areas.

POPULAR AREAS

The 1948 and 1949 observations provide some interesting information on the relative popularity of different fishing areas (Tables 1 and 2). The tables, which summarize all observations over the 18-month period of study, cover totals of 3,253 anglers in 1948, and 7,246 in 1949, and embrace the results of 445 surveys in 1948, and 841 in 1949.

The best measure of the popularity of angling localities in the delta is provided by the average number of anglers seen per station per survey. The constancy of the popularity of certain places is also seen by comparing figures for the two years. Station 23 (Sacramento River, from Isleton to the Grand Island Sounding Board), for instance, was the most popular angling site in both years (27.72 anglers per observation in 1948, and 21.21 anglers in 1949). The ranking of the other stations was not the same in both years, but 11 of the 12 most popular fishing sites in 1948 were also among the first 12 in 1949. At these popular sites (with a few exceptions such as Stations 23 and 15), the 1949 counts of anglers were slightly higher than those for 1948. The average for all stations show 7.31 anglers per station in 1948 and 8.60 for 1949. Reference to Figure 2 will reveal, however, that the figures are not comparable, since the same period of months was not covered in the sampling periods for each year; October and November, months of heavy fishing in 1948, for example, were not covered in 1949. When the computation of the average is based only on the data for those months that were sampled in both years, *i.e.*, April through September, the figures become 6.23 anglers per station per survey for 1948 and 9.47 for 1949.

TABLE I

Summary of Data on Angling in the Delta in 1948

Station no.	Number of surveys	Total numbers observed				Average number per survey			
		Boats	Boat anglers	Shore anglers	Total anglers	Boats	Boat anglers	Shore anglers	Total anglers
1	18	3	5	25	30	0.17	0.28	1.39	1.67
2	18	14	31	25	56	0.78	1.72	1.39	3.11
3	19	4	8	75	83	0.21	0.42	3.95	4.37
4	19	1	2	2	4	0.05	0.11	0.11	0.21
5	19	57	138	21	159	3.00	7.26	1.11	8.37
6	18	13	32	7	39	0.72	1.78	0.39	2.17
7	19	34	91	6	97	1.79	4.79	5.32	5.11
8	14	3	8	16	24	0.21	0.57	1.14	1.71
9	19	22	49	43	92	1.16	2.58	2.26	4.84
0	19	44	99	31	130	2.32	5.21	1.63	6.84
1	14	3	6	50	56	0.21	0.43	3.57	4.00
2	10	3	7	3	10	0.30	0.70	0.30	1.00
3	19	17	38	1	39	0.89	2.00	0.05	2.05
4	19	42	99	2	101	2.21	5.21	0.11	5.32
5	19	140	322	4	326	7.37	16.95	0.21	17.16
6	19	40	86	42	128	2.11	4.53	2.21	6.74
7	19	63	124	95	219	3.32	6.53	5.00	11.53
8	18	31	76	48	124	1.72	4.22	2.67	6.89
9	18	26	60	40	100	1.44	3.33	2.22	5.55
0	18	113	258	81	339	6.28	14.33	4.50	18.83
1	18	9	21	118	139	0.50	1.17	6.56	7.72
2	18	12	24	63	87	0.67	1.33	3.50	4.83
3	18	110	244	255	499	6.11	13.56	14.17	27.72
4	18	32	72	128	200	1.78	4.00	7.11	11.11
5	18	35	88	84	172	1.94	4.89	4.67	9.56
Totals	445	871	1,988	1,265	3,253	--------	--------	--------	--------

The most popular fishing sites at the time of the study were: Sacramento River, from Isleton to the mouth of the river; San Joaquin River rom the mouth of Mokelumne River to Seven Mile Slough, from Three Mile Slough to False River, and from Blind Point to Mayberry Cut; Venice and Mandeville Cuts; South Fork of Mokelumne River in the vicinity of Terminous; Mokelumne River from Georgiana Slough to Jackson's Harbor; and Georgiana Slough from Tyler Island Bridge to the mouth of the slough. The amount of angling consistently noted in these areas was impressive. As noted above, Station 23 on Sacramento River averaged 27.72 anglers per survey in a series of 18 counts in the 1948 season. The same area, in 33 surveys in 1949, had an average of 21.21 anglers. At times, as many as 82 fishermen were seen in a single observation. Station 15 on San Joaquin River averaged 17.16 anglers per survey n 1948, and 15.24 in 1949 (109 were seen on one occasion). Station 14, on Venice and Mandeville Cuts, with 104 anglers, Station 12, on San Joaquin River, with 99 anglers, Station 3 on Coney Island Cut, with 99 anglers, Station 25, on Sacramento River, with 90 anglers, and Station 4, on Victoria Canal, with 83 anglers, are additional examples of notable concentrations of sport fishermen on single occasions.

Although both boat and shore fishermen contributed to the remarkably high counts, it is of interest to note the proximity of the most popular ishing sites to liveries where launches and skiffs are available to fishermen. Station 15 on San Joaquin River is just around a bend of the river

TABLE 2

Summary of Data on Angling in the Delta in 1949

Station no.	Number of surveys	Total numbers observed				Average number per survey			
		Boats	Boat anglers	Shore anglers	Total anglers	Boats	Boat anglers	Shore anglers	Total anglers
1	33	14	30	54	84	0.42	0.91	1.64	2.55
2	33	20	48	138	186	0.61	1.45	4.20	5.65
3	33	20	43	72	115	0.61	1.30	2.18	3.48
4	33	4	8	13	21	0.12	0.24	0.39	0.63
5	33	64	141	58	199	1.94	4.27	1.76	6.03
6	33	59	129	5	134	1.78	3.91	0.15	4.06
7	33	70	175	9	184	2.12	5.30	0.27	5.57
8	32	8	18	90	108	0.25	0.56	2.81	3.37
9	33	40	87	83	170	1.21	2.64	2.51	5.15
10	33	52	125	131	256	1.57	3.78	3.97	7.75
11	32	11	26	130	156	0.34	0.81	4.06	4.87
12	32	8	19	131	150	0.25	0.59	4.09	4.68
13	33	16	32	181	213	0.48	0.97	5.48	6.45
14	33	179	413	41	454	5.42	12.51	1.24	13.75
15	33	217	487	14	503	6.57	14.82	0.42	15.24
16	33	79	184	137	321	2.39	5.57	4.15	9.72
17	33	111	278	188	466	3.36	8.42	5.70	14.12
18	33	59	140	261	401	1.79	4.24	7.91	12.15
19	33	35	79	191	270	1.06	2.39	5.79	8.18
20	33	156	337	113	450	4.72	10.21	3.42	13.63
21	33	19	39	425	464	0.57	1.18	12.88	14.06
22	33	33	78	183	261	1.00	2.36	5.54	7.90
23	33	161	351	349	700	4.88	10.64	10.57	21.21
24	33	52	104	237	341	1.57	3.15	7.18	10.33
25	33	70	155	394	549	2.12	4.70	11.93	16.63
26	19	4	7	83	90	0.21	0.37	4.36	4.73
Totals	841	1,561	3,533	3,711	7,246	--------	--------	--------	--------

from six boat liveries, and Station 20 on Mokelumne River lies in the midst of this same group of six boat-rental establishments. Station 7 on False River is situated near the popular Frank's Tract, with its cluster of six liveries. Station 14 on San Joaquin River has one boat livery close at hand, and Station 23 on Sacramento River near Isleton is served by three rental docks. Station 17 on San Joaquin River has the benefit of six boat liveries, all located on the south shore in the vicinity of Antioch. Reference to Tables 1 and 2 will disclose that these particular stations rank high in point of number of boat anglers observed. Some of them, such as Stations 17 and 23, are also frequented by numbers of shore anglers.

Those stations supporting the greatest numbers of shore fishermen in both years were Station 21 on Georgiana Slough, Stations 23 and 24 on Sacramento River, and Station 17 on San Joaquin River. Station 25 on Sacramento River was popular for shore fishermen in 1949, but held a mediocre rank in 1948. Station 18, as relocated in 1949, on the South Fork of Mokelumne River apparently also increased in popularity from 1948 to 1949, for the months surveyed. Much of this increase can be attributed to the relocation, with more shore anglers in evidence. These stations, which proved to be the most popular, are all easily accessible by automobile. This fact undoubtedly contributed materially to their heavy use by shore anglers, although many other areas that can be easily reached by road did not approach these in popularity.

TABLE 3

Average Number of Anglers Observed Per Station Per Survey, by Months, 1948 and 1949

Month	1948			1949		
	Boat anglers	Shore anglers	Total anglers	Boat anglers	Shore anglers	Total anglers
January	----------	----------	----------	2.04	1.68	3.72
February	----------	----------	----------	6.64	2.68	9.32
March	----------	----------	----------	1.58	3.05	4.63
April	6.39	2.90	9.29	7.96	6.99	14.95
May	4.51	2.59	7.10	5.98	4.32	10.30
June	2.67	2.38	5.05	2.48	4.00	6.48
July	2.18	3.25	5.43	2.93	6.36	9.29
August	1.93	2.92	4.85	2.89	4.58	7.47
September	2.65	3.74	6.39	4.82	5.64	10.46
October	14.04	4.87	2.71	----------	----------	----------
November	20.02	2.71	22.90	----------	----------	----------
December	3.81	0.91	4.72	----------	----------	----------

It should be emphasized that our sampling locations were determined by the requirements of our general program and hence many of the most popular fishing areas in the delta were not covered in the present survey. Frank's Tract, for instance, was not included in our observations. Although Station 7 on False River lies on the northern boundary of Frank's Tract, only the anglers within the station itself, on False River, could be counted successfully. Among other popular areas not touched in these surveys were Sherman Island Lake and Big Break on Dutch Slough.

MONTHLY TRENDS

The data on monthly fluctuations of angling pressure have been arranged to permit the comparison of trends in 1948 and 1949 (Table 3 and Figure 2). The trend during the months in which counts were made in both 1948 and 1949, April through September, agree rather faithfully. The 1949 values were higher than those for 1948, and the increases and decreases for the two years were not always proportional, but the trends were in the same directions for the six months involved. For example, numbers of anglers per station per survey were lower in May than in April in both 1948 and 1949. Furthermore, in both years June was lower than May, July was higher than June, August was lower than July, and September was higher than August. When the figures on shore anglers are considered in relation to those of the boat anglers, it is seen that the principal part of the fluctuations in 1948 were due to boat anglers; counts of shore anglers were far more stable than those for boat anglers. This relationship, in general, held for 1949 also, but it was not as clear-cut as in 1948.

The most striking feature of these figures is the high value of the October and November averages in 1948. The advent of fishing for large striped bass, which begins in September or October and continues through the winter and into the spring, coincides with these high values. The beginning of the upward trend is seen in the average for September, 1948, when an increase over summer month counts occurred. The same trend appeared in September, 1949.

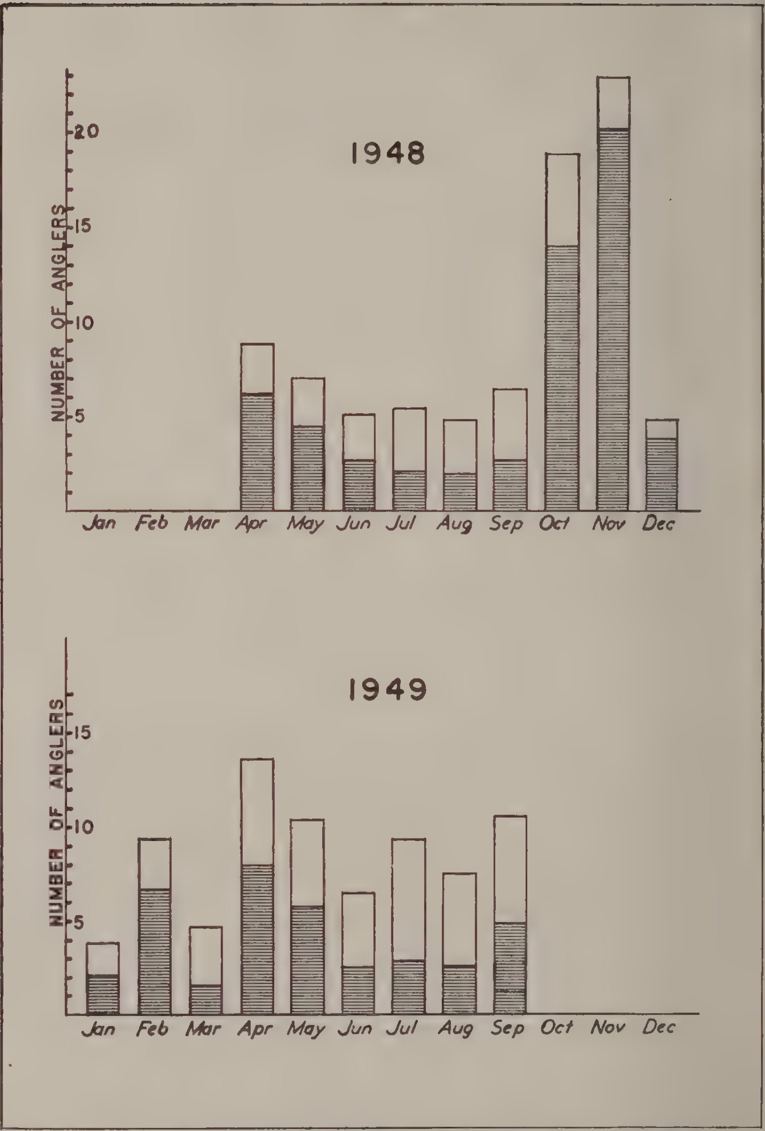

FIGURE 2. Average number of anglers per station by month, all stations, 1948 and 1949. Shaded areas denote boat anglers, clear areas denote shore anglers.

TABLE 4

Total Numbers of Anglers and Numbers of Anglers Per Station Per Survey, According to Days of the Week

Item	Monday		Tuesday		Wednesday		Thursday		Friday	
	1948	1949	1948	1949	1948	1949	1948	1949	1948	1949
Number of boat anglers	178	No observations made	504	1,758	338	1,148	488	628	469	279
Number of shore anglers	224		301	695	243	1,382	246	1,368	236	426
Total number of anglers	402		805	2,453	581	2,530	734	1,996	705	705
Boat anglers per survey	2.66		4.75	7.10	3.10	3.59	5.81	2.51	6.01	4.44
Shore anglers per survey	3.34		2.84	2.76	2.23	4.33	2.93	5.49	3.03	6.74
Total anglers per survey	6.00		7.59	9.86	5.33	7.92	8.74	8.00	9.04	11.18

The low counts of December, 1948, are explainable on the basis of poor weather. Subnormal temperatures prevailed in the delta area throughout the month, and unusual ice formation in quiet waters in the delta was noted on several occasions.

TRENDS WITHIN THE WEEK

The study of trends in fishing pressure within the week is handicapped by a paucity of counts on Saturdays and Sundays. Comparisons between 1948 and 1949 are limited further by the lack of counts on Monday in the latter year. Presentation of data in this section, therefore, is limited to Monday through Friday in 1948 and Tuesday through Friday in 1949 (Table 4 and Figure 3). The data on weekday fluctuations are based on counts made in all months of observation.

Even with the limitations just outlined, however, some interesting relationships can be recognized. The 1949 figures for number of anglers per station per survey are obviously somewhat higher than those for 1948. Further, the greater variability in the numbers of boat anglers as compared with the numbers of shore anglers described earlier in the section on monthly trends is to be found also in the figures on daily trends. For the four weekdays for which there are data in both years, Friday had the highest and Wednesday the lowest average counts. Tuesday and Thursday did not hold the same rank in both years, but each was either second or third in importance in both 1948 and 1949.

RATIO OF SKIFFS TO LAUNCHES

It was mentioned earlier that in 1948 no breakdown was made of boat anglers into those in launches and skiffs. Some figures on this point are available for 1949. The 1949 counts were not treated by month or by day of the week, but are presented here for the season as a whole. In the 1949 surveys, 1,534 boats were counted. Of this number, 1,273 were skiffs, either with or without outboard motors, and the remaining 261 were inboard-powered launches of various sizes. The ratio of skiffs to launches for 1949, therefore, was approximately 5:1. The total number of boats counted in the 1948 surveys was 870; if the same 5:1 ratio applied in that year, there would have been about 725 skiffs and 145 launches.

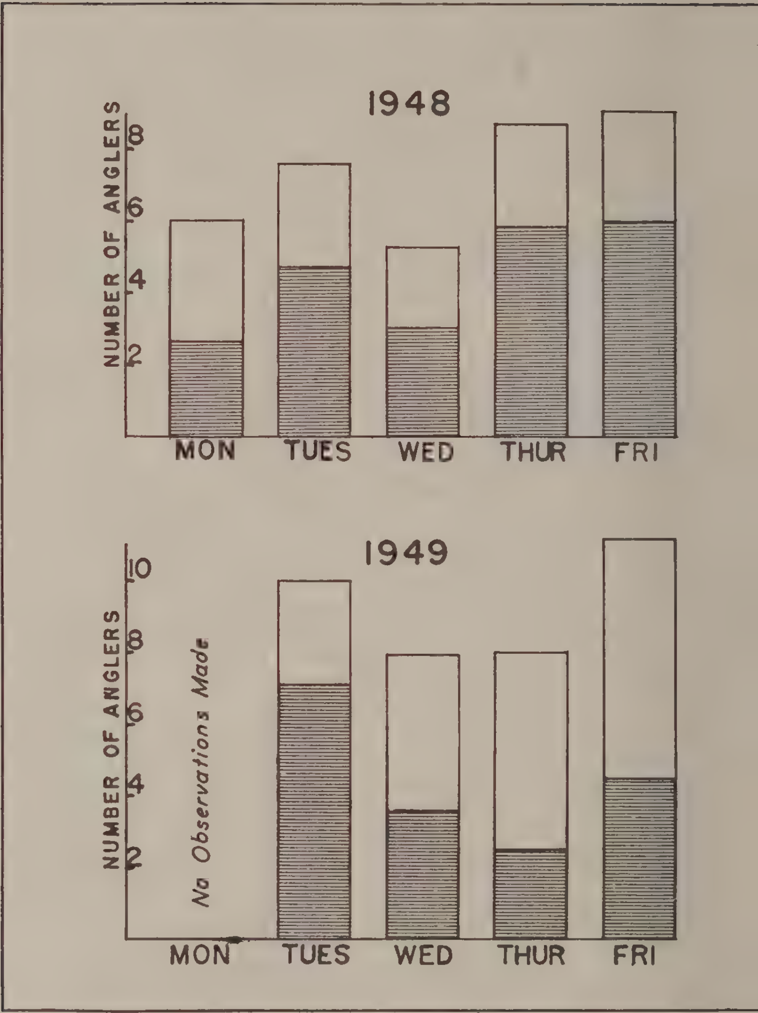

FIGURE 3. Average number of anglers per station by weekday, all stations, 1948 and 1949. Shaded areas denote boat anglers, clear areas denote shore anglers.

TOTAL ANGLING EFFORT

It would be highly desirable to know the total number of anglers using delta waters in a year's time. The present data do not permit treatment for an accurate determination of such a total, since certain accessory information is lacking. In the absence of reliable figures concerning the hourly turnover of anglers in the delta, any attempt to project the present data into an annual total would be little more than a rough estimate. On the other hand, even an approximate value will indicate the order of magnitude, and will be of interest to all who fish in the delta.

If we assume that the average delta angler fishes for a half-day, and that in 1948 the average number of anglers per station per survey was approximately seven, and that the corresponding number for 1949 was 10, the following estimates of annual values are obtained: 1948, 91,000; 1949, 130,000. It should be emphasized that these figures represent only the number of weekday anglers using the localities here discussed. Saturdays and Sundays, which would probably each support more anglers than a week's days combined, are not included. Another point not considered here is the great number of delta localities lying outside the area of this study. These localities include not only those places between sampling stations on the various channels, but several particularly active sites, such as Frank's Tract, Sherman Island Lake, and Big Break on Dutch Slough. No attempt is made here to extend the present estimate to include weekends or other areas.

SUMMARY

During the course of biological investigations in the Sacramento-San Joaquin Delta in 1948 and 1949, Fish and Wildlife Service personnel made routine surveys of the numbers of sport anglers present at collecting stations while net tows were being made. Twenty-five stations were visited at intervals from April, 1948, through April, 1949, and 26 from May, 1949, through September, 1949.

The monthly averages of the numbers of anglers observed per station per survey indicate that for those months in which observations were made in both 1948 and 1949 (April through September), the trends from month to month followed each other closely in the two years. The actual counts in 1949, however, were higher than those in 1948. Fishing pressure in October and November, 1948 (no counts were made in those months in 1949), was heavier than in other months of the year. The fluctuations from month to month can be attributed largely to changes in boat angling pressure, since the numbers of shore anglers remained nearly constant from month to month.

Average counts on different days of the week revealed angling pressure to be highest on Fridays and lowest on Wednesdays in both 1948 and 1949. (No data were collected for Saturday or Sunday in either year or for Monday in 1949).

Average counts for the different localities proved that the most popular areas in 1948 were popular in 1949, as well.

It is estimated roughly that 91,000 anglers fished observed waters in 1948, and 130,000 anglers used them in 1949. This estimate does not include Saturdays or Sundays, or areas not included in the survey.

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SOME MODERN METHODS OF FISH DETECTION

Echo Sounding, Echo Ranging and Aerial Scouting

By

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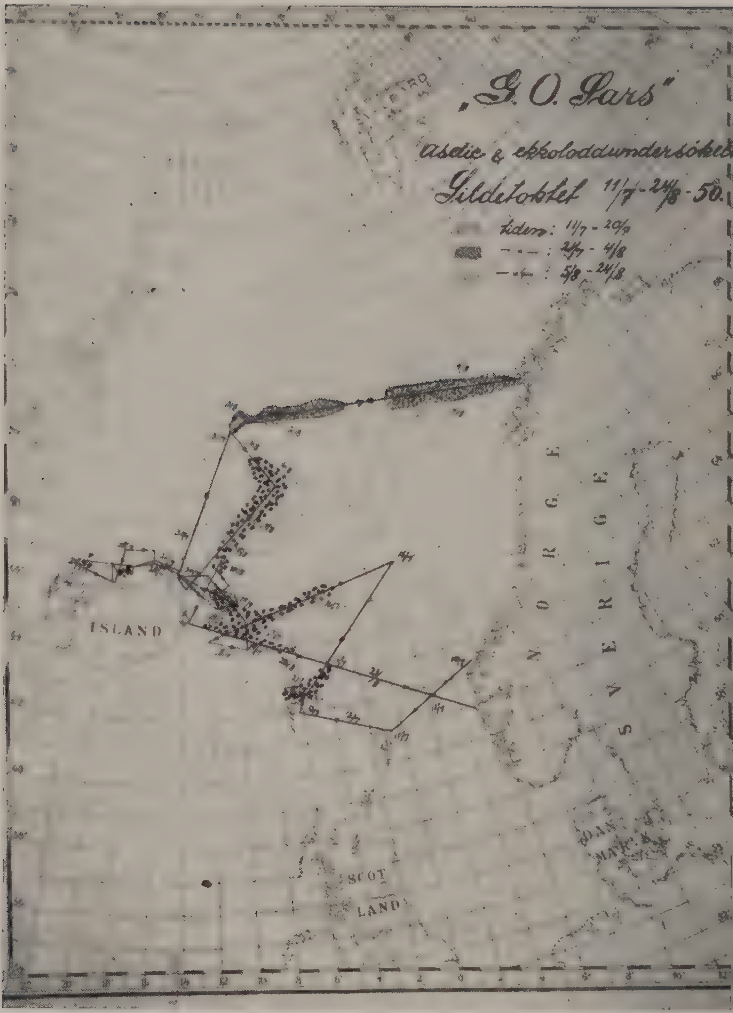
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ISLAND
NORGE
SVERIGE
SCOT LAND

Figure 1. The Norwegian research vessel, *G. O. Sars*, is equipped with both echo sounders and Asdic. This diagram shows an area searched for herring by the *G. O. Sars*; the waters where herring were located are indicated by stippling.

SOME MODERN METHODS OF FISH DETECTION[1]

Echo Sounding, Echo Ranging and Aerial Scouting

The fishing industry had started to utilize electronic equipment ɔr facilitating navigation and even locating fish during the last few ɜars before World War II. Since the end of the war there has been a ιpid development in this field, and today the radio-telephone, direc- on finder and echo sounder are standard equipment on the modern shing vessel. Another important development — the use of aircraft ɔr spotting fish — has become an established practice in some parts the world. It is particularly useful because it detects surface shoals ɔr which echo sounding is frequently of limited value.

. Echo Sounding

Although the fisherman has also benefited from other recent ad- ances in science and engineering, it is safe to say that of all the tools his trade acquired during this period, the common use of the echo ounder for detecting fish must be considered the outstanding develop- ent of commercial fisheries. Electronic fish detection is already imulating the development of new fishing gear, such as the mid- ater trawls, and is taking much of the guess-work out of fishing with e old and established gear in both the pelagic and demersal fisheries.

) HISTORY OF ITS USE IN FISHERIES

Before World War II, navigational echo sounders were, in the ain, visual instruments. Paper recorders were in existence, but they me into general use only during and after the war. Although Skip- er H. Balls, of Great Yarmouth, England, was able to use a visual strument successfully in fishing as long ago as 1933, it was the paper recorder with its pictorial "memory" of the searched section of t sea that caught the imagination of the fishermen.

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[1] This article was compiled by FAO from sections written by experts the particular fields. Dr. D. H. Cushing, Senior Scientific Officer, isheries Laboratory, Lowestoft, England, contributed the material on ho sounding ; Finn Devold, Senior Scientific Officer, Norwegian Fisher- s Research Institute, Bergen, Norway, contributed the material on ho sounding and Asdic in Norwegian Fisheries ; John C. Marr, Chief, outh Pacific Fisheries Investigations, United States Fish and Wildlife ervice, 450-B Jordan Hall, Stanford, California, U.S.A., contributed the aterial on aerial scouting for fishes, published by permission of the irector of the U. S. Fish and Wildlife Service. H. Kristjonsson, FAO heries technologist, supplied further material from Iceland and compiled e article.

At the instigation of Dr. W. C. Hodgson (Fisheries Laborato Lowestoft. England), Skipper Balls converted the so-called " parasiti or extraneaous noises of the visual sounding instrument into relia indices of fish. Not only was he able to distinguish various types echo due to the different types of behavior of the herring in the No Sea, but to establish quite clearly that in the summer fishery off No Shields, he could catch twice as many fish when he used the ec sounder. During 1933-37, 399 shots without the use of the sound yielded a mean catch of 11.41 crans (1,945 l.) ; 69 echo shots yiel ed a mean catch of 25.66 crans (4,374 l.). Although a great de of research has been carried out on echo sounding for herring in t United Kingdom since then, the results of Skipper Balls' work (Bal 1946) would represent a very adequate summary of it.

The paper recorder was first used in fisheries by Oscar Sund (193 Norwegian marine biologist. The echo sounder was originally ma to measure the depth from a moving ship. but Sund hoped that

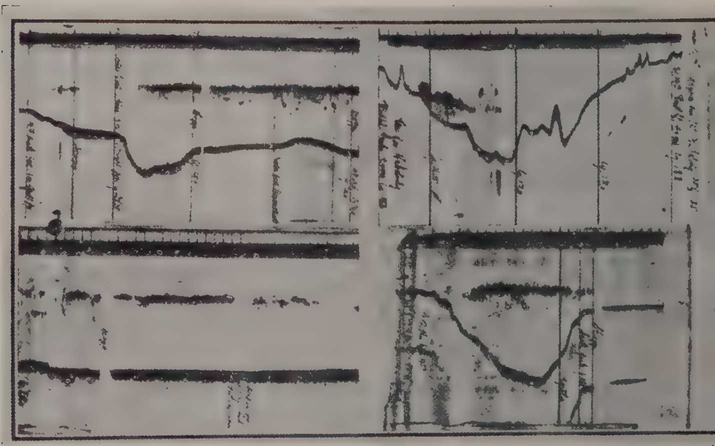

Figure 2. Reproduction of the first registrations of fish made on the echo soun er. These four echo records, made by Sund in 1935, show traces of spawni cod in mid-water at Lofoten. In the left hand diagrams, the ship is stopped part the time. The bottom right hand record is somewhat disfigured by oscillatio set up by excessive shaking of ship's motor ; but it shows also a second ec from the bottom, reflected from the surface. Marks on top of each diagram a produced every minute and are 6.7 mm. apart. The thick horizontal lines at t top of the pictures represent the surface, the uneven curves being the sea-be between these lines the registrations of shoals of cod can be seen. The distan the ship has sailed is given in nautical miles by the vertical lines running throu the picture. It is easily seen that the shoals of cod in Lofoten can extend ov several miles. Further, the recordings show that the fish shoals stand at the sa depth irrespective of the shape of the sea botton.

ould also be possible to register shoals of fish appearing between the ip and the sea bed.

In 1935, he managed to procure the necessary funds to buy a ritish Admiralty-type echo sounder, which, subsequently, was in- alled on board the research vessel *Johan Hjort.* In March of the same ear, Sund discovered that the echo sounder did register the compact oals of spawning cod in Lofoten and published reproductions of ese first registrations (Sund, 1935). (*See* Figure 2).

Before echo sounders were introduced into the cod fisheries, the shermen would discover the shoals by trial and error. They would wer their lines in different places and to various depths. Even when ey caught fish, they could not be certain that the fishing was car- ed out where the shoals were most compact. With the help of the ho sounder, the shoals could be located, their density estimated, d the depth at which they stood determined. When Sund told e fishermen this story, very few were willing to believe it. Regis- ation of cod shoals with an echo sounder was thought so improbable at the representatives of the fishermen even declined any such ssistance offered to them. Only when some of the fishermen them- lves had bought and tried the echo sounders were they convinced at it really was possible.

During the last few years, following demands from fishermen, a orwegian vessel has been given the sole task of locating the shoals of od during the Lofoten season. By reference to special grid charts, e fleet is informed by wireless of the abundance of cod in the differ- nt localities.

Not only the shape of the bottom, but also the nature of the sea ed can be determined from the recordings. Echoes from a rock bot- om give a sharply defined registration, a sandy bottom gives a broad- r, more diffuse curve and, where there is a clay bottom, the registra- on shows the surface of the layer of clay and the foundation on hich it rests. The last fact led to an important discovery.

In the summer of 1935, Gunnar Rollefsen, on board *R/V Johan jort*, was carrying out investigations on the occurrence of cod fry. e used an ordinary prawn trawl for the investigations in deep water, nd found that where the echo sounder recorded a double bottom, at is, a clay bottom, rich catches of prawns were obtained, as prawns refer such a bottom. With an echo sounder it was possible to map e prawn fields in a short time. During the same summer, several ew prawn fields were mapped; the work was continued in the following ears. Through this discovery, rich prawn fishing, running into mil- ons of Norwegian kroner, was started in northern Norway. Rollefsen escribed this discovery in a report on the Norwegian prawn fishery Hjort and Ruud, 1938).

Experience showed that the echo sounder could locate, not only od and prawns, but also any kind of pelagic fish appearing in suffi- iently large shoals. Each winter, large shoals of herring migrate to e west coast of Norway to spawn. When the echo sounder was ried during the winter herring season in 1936, it was found that apart from detecting the shoals, it was possible to determine if they were sufficient density to make fishing with a purse seine worth while, whether they were so dense that only part of the seine should be use to avoid damage to the gear through too big catches. The advantag of using echo sounders in the herring fishery became so obvious th a few progressive Norwegian fishermen purchased echo sounders t same year.

In Europe, echo sounders are now widely used in fishing. It estimated that 80 to 90% British, 70% of the large Norwegian an Swedish, 60% Dutch, 43% Icelandic, 31% Belgian and 18% Danis fishing vessels are fitted with echo sounders. Besides being an important navigational aid, this equipment has been used for such d verse purposes as charting shellfish areas (Chestnut 1950) in the Unite States, and catching squid (Mishima 1951) in Japan.

(*b*) USE OF THE ECHO SOUNDER IN NORWEGIAN FISHERIES

Since World War II, most of the large fishing vessels in Norwa (about 70% of the fishing fleet) have been equipped with echo sounders and the annual yield of the herring fishery has become about thre times as great as it was during the period between the two worl wars. This great expansion of the herring fishery can be attribute to some extent to the use of echo sounders. A purse seiner withou an echo sounder must try to find the herring according to previous experience as to where the herring usually appears. Then a small boa rowed by two men, searches the probable fishing area. The maste seiner stands in the stern of the boat which is equipped with a thi wire to which is attached a plummet. When the wire is lowered int a herring shoal, an experienced master seiner can judge by the vibrations of the wire whether profitable fishing can be carried out. If n herring is found, the dinghy must be taken on board the purse seine and the whole procedure must be repeated in another place. If herring is found, the master seiner must try to estimate the density of th shoal to decide where to cast the seine. He directs the two seinin boats into the right position as regards wind and current, and give the order where to cast the seine. Long experience is required of th master seiner for this fishing.

A modern Norwegian purse seiner is equipped with an echo sounder. The vessel can search the area at full speed. From the ech sounder records the master seiner who knows his job can decide whether it is worth attempting to fish. When fishing is to be tried, a moto boat, equipped with a smaller type echo sounder, is lowered into th water to determine where the chances for a good catch are best.

The shoals of herring migrating to the Norwegian coast for spawning form the basis of the most important herring fishery in the country. In the last few years, the herring have arrived in January an have left the coastal waters in March, the fishing season thus lastin only two months at the stormiest time of the year. In spite of this, th fishermen annually landed herring having a gross value of about 15 nillion Norwegian kroner during the last few years. In this herring ishery, time is money to a very high degree. Echo sounders certainly lo save the fishermen considerable time, not only when it comes to ocating the herring, but also during the actual fishing. No time is vasted by casting on shoals too small for profitable catches or so dense hat the gear may be damaged or lost.

Until recently, not much was known about the whereabouts of he Norwegian herring outside the spawning season when it appears ff the Norwegian coast. It is of great scientific and practical interest o solve this problem. If herring could be found in the open sea, nd in such concentrations that profitable fishing could be undertaken, t would be of value to the food supplies of northern Europe. As early s 1873, the Norwegian zoologist, G.O. Sars, advanced the theory that he Norwegian Sea was the home of this tribe of herring. (He defined the area as the waters between Norway, Scotland and Iceland). n 1944, the Icelandic fisheries biologist, Arni Fridriksson, published he hypothesis that the herring being fished off north Iceland in the ummer spawned off the Norwegian coast in spring. Morphologially there was no difference between the herring from these waters, nd Fridriksson felt that the spawning grounds of such great quantities f herring as appeared off north Iceland could not have escaped disovery.

Herring tagged off the north coast of Iceland in the summer of 1948 were fished off the west coast of Norway in the spring of 1949 nd 1950 - proving beyond doubt that some of the herring migrated rom Iceland to Norway (Fridriksson and Aasen, 1950).

In 1949, Norway undertook a preliminary search for the route aken by the herring during their migration between the spawning and eeding grounds. Herring, which appeared to have spawned off the Norwegian coast earlier in the year, were found north of the Faroe Islands in May/June. In July, large concentrations of herring were found east of Iceland, and in the waters around Jan Mayen. Samples seemed to indicate that they were mature, belonging to the Norwegian tribe.

(*c*) USE IN ICELANDIC COD FISHERY

In the Icelandic cod fishery the fishermen rely heavily on indications of fish on their recording echo sounders, at least supplementary to other factors, such as known fishing grounds. This applies equally to trawling, long-lining and set netting. Recently the big steam trawlers have been using mid-water trawls successfully for fishing on shoals of spawning cod a few fathoms above the bottom, detected by echo sounding.

(*d*) ECHO SURVEY

So long as fishing boats aggregate on patches of fish, a form of fleet searching takes place ; this may be organized as it is in Norway (Eggvin 1950) or it may be based on the spread of information about the catches by radio and in the port. If the patches of fish are large the searching efficiency of the fleet depends upon its size. For thi reason the fairly large drifter fleets employed at Frazerburgh, Scotland in the summer or off East Anglia, England, in the autumn, tend to aggregate all over the area where fish are revealed by the echo survey The smaller drifter fleet off the Northumberland coast, however, usuall fishes on the edge of the fish patch nearest the home port (Cushing 1952) ; the same effect was noticed by Eggvin (1950) in the use o the echo service of the Norwegian fishing fleet.

In a United Kingdom ring-netter fleet, so long as there is a sufficient number of boats, the behavior of the fleet is a form of survey, fo each boat relies on the information given by its echo sounder and o the behavior of the neighboring vessels. Driftermen, however, using the fish trace only as an additional sign of fish, aggregate on a fish patch much less regularly. A form of systematic echo survey might well accelerate their rate of aggregation.

Runnström (1941) and Sund (1943), off Norway, and Tester (1943), off British Columbia, have counted fish traces along an irregularly arranged cruise track within the area that the fleets were searching. Another form of survey, first used in 1948, is described by Cushing (1952). Here the cruise grid was arranged not only over the area in which the fleets were operating, but also over a region extending quite widely from that area. Fish traces were reduced to numbers of soundings on fish ; thus, each sounding can be examined for the presence or absence of fish. Then the number of soundings on fish per distance can be combined on the cruise grid to show patches of pelagic fish. It will be shown below that the identification of any trace, even when the ship is stopped, is subject to certain limitations. Identification of traces, taken when the ship is steaming at full speed, is even less accurate ; hence a general form of identification, analogous to that used by the fisherman when he goes to a particular place at a certain season expecting a catch of a particular fish, should be used. Patches of pelagic fish were compared with drifter landings off East Anglia generally identifying the fish as herring ; in the English Channel, patches of pelagic fish were compared with patches of pilchard eggs, generally identifying the fish as pilchards.

Krafft and Schüler (1951) steamed over the whole of the North Sea, north of the Dogger Bank, where they made indices of fish abundance using the depth of each trace and its extent in depth. This is a valid method if the noise level in the sea is constant, (at the moment a returned signal can only be measured relative to the very variable amount of noise), if the power output is constant, and if the amplifiers are not overloaded. It is unlikely that all these conditions can be fulfilled over a long cruise, using a commercial sounder. However, along the cruise track, these indices were compared with the contemporaneous herring landings from luggers and a rough relation between the two variables was shown.

Echo survey has sometimes been extended in scope by identifying each trace by some diagnostic character (Richardson, 1950 and 1951 ; Parrish and Craig, 1951). Richardson has used this form of urvey to find sprat shoals. In the Southern Bight of the North Sea, n January, sprats were distinguished by the comet shaped character f their echo trace (Hodgson 1950) ; this is not universally diagnostic f sprats alone, but it is valid in this area at this time, for the patch vas shown to coincide with a series of sprat shoals, landed from the utch coast. The same type of survey has been used by Parrish and raig in the Scottish Frazerburg fishery. Here, herring were identiied as "plume" shaped traces. The patches so described were signifiantly correlated with drifter landings, showing that a general identifiation may be made to the effect that these fish were herring ; these races were not found at night, indicating a change in behavior. If dentification of each trace is not made, the estimate of abundance vill include all pelagic fish. If, however, identification of each trace s made, then the estimate of abundance will include other fish that nake the same sort of trace and exclude the desired fish when traces re made that are different due to a change in behavior.

e) Fish Identification

In areas having several species of fish, dispersed or in small shoals, he use of the sounder by fishermen and its use on survey is still limted unless an identification of the traces can be made. Many fishrmen will say that they have shot on a trace that "looked like erring" and have caught mackerel, horse mackerel, sprats or pilchards.

Renou and Tchernia (1947) were the first to publish traces of diferent fish. They drew no conclusions about the difference between pecies, but pointed out that they had found three types of trace, all f which were almost certainly herring. In 1950, Hodgson was the irst to discriminate between different fish species in United Kingdom vaters. Of various traces, the comet shape was assigned to sprats ; adoids were identified by the spotty appearance and mackerel by the hin character with striated marks. Pilchard and herring both had leep plume-shaped traces, the first of which was very black-edged and he second of which had a diffuse edge. Each of these identifications vas made by direct observation, using a "ripper" (a weighted bunch f hooks jerked by hand through the water in a shoal of fish in order o foul-hook a fish) or by fishing with a ring net.

Traces of spawning cod were published by Sund (1943) and Kristensen (1950) ; these have both the spotty character assigned to gadoids y Hodgson and the more diffuse layered record from deep water that as come to be regarded on board the *Ernest Holt* as characteristic of Arctic cod. Krefft and Schubert (1950) showed that compact hering shoals fairly near the bottom in daytime break into irregular diffuse shoals as they climb into the upper water at night. Shubert (1950) as published a very characteristic trace of tuna near the surface on the Fladen Ground in the northern North Sea. These large fish make very dense and sharply irregular traces. Capelin from the Newfoundand Banks take up the well-known comet appearance (Tchernia, personal communication). In the Barents Sea (cruise reports, *Ernest Holt*), these fish tend to be irregularly distributed in layers. In 170 fathoms off Iceland, a comet shape is given by cod shoals on the bottom. In fresh water, perch records take up the comet shape, whilst those of *Coregonus Wartmanni* (Schärfe, 1951) take up the spotty gadoid appearance. Thus, diagnostic confusion can easily take place, between fish of different species, between fish of the same species behaving differently, and between fish of different species behaving in the same way.

Generalizing from Hodgson's criteria, four types of trace may be distinguished :

(1) The gadoid spot, which is a very small compact shoal, characteristic of cod, pollack and *Coregonus*. The compactness of the trace itself depends to a certain extent on the paper speed of the machine.

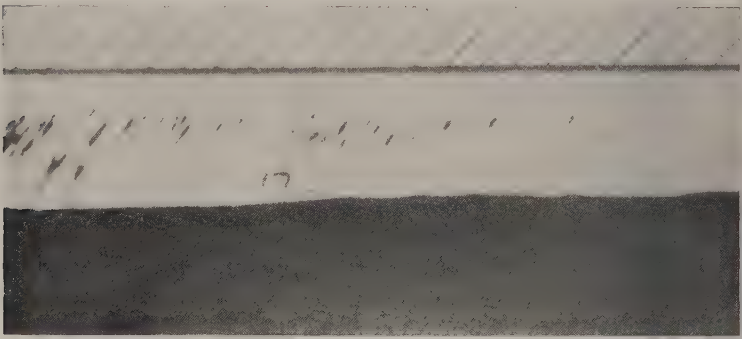

Figure 3. Spot traces observed at full speed between Ruytingen and Dyck Banks, off Calais, December 1951. Not identified.

(2) The comet shape, made by a shoal smaller than the conic section of the sound beam, crossing the beam at a constant depth. This

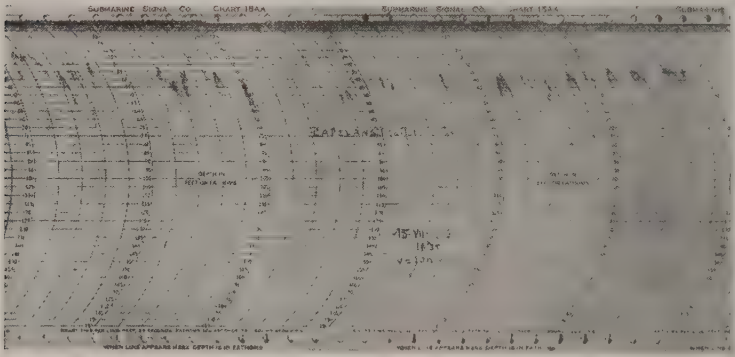

Figure 4. Comet-shaped traces observed off the Grand Banks of Newfoundland, identified as capelin (*Mallotus villosus*). Reproduced by permission of P. Tchernia.

is characteristic of sprats and young herring in the North Sea, capelin off Newfoundland, cod in 170 fathoms off Iceland and perch in the Bodensee.

(3) The plume shape, made by a shoal larger than the sound beam, and extending for a considerable distance in depth, but not large enough to make a continuous layer. This is the commonest type of shoal in shallow seas and has been assigned to herring, pilchard and mackerel. It will be shown below that the diagnostic differences in intensity pointed out by Hodgson are possibly due to differences in shoaling density and the presence, or absence, of an air bladder.

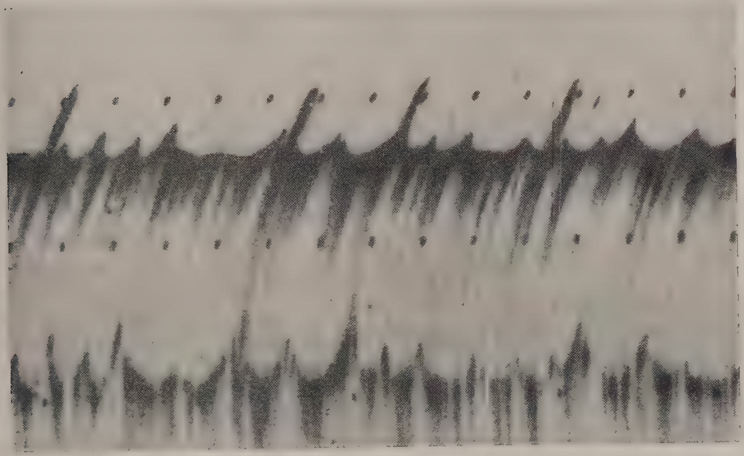

Figure 5. *Plume*-shaped traces springing from the bottom in clear water off Flamborough Head in October 1951. Identified as herring ; note that the fish traces are not reproduced in the second echo.

(4) A layer made by a large and continuous shoal. It may be uniformly diffused (the post larval pilchards of Burd and Lee (1951) in the English Channel) or aggregated and irregular (spawning herring — Renou and Tchernia (1947) and Lowestoft observations on the Sandettie Bank near the Straits of Dover, in December). (*See* Figure 6)

The difference between the types of trace given in this classification are due to differences in the size of shoal relative to the area covered by the sound beam at the depth of the shoal. It is interesting to recall that Marchena, in a notable paper, (1951) gave all four types of traces as characteristic of the sardine in varying depths of water off Portugal. Fishermen must know whether the trace on which they shoot is made by the fish they want. A particular trace must be iden-

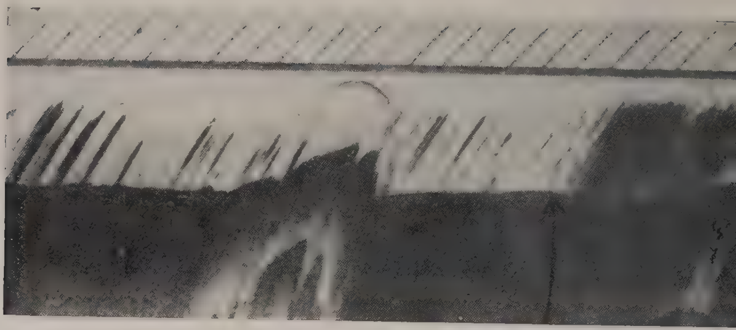

Figure 6. Layer traces observed between the Ruytingen and Sandettie Bank in thick water near Calais in December 1951. Identified as herring.

tified and it is clear than this cannot be done with certainty. However, a general form of identification can always be made ; for example, the pelagic fish off East Anglia, England, in the autumn are likely to be herring and each skipper from Scotland, England, Holland and Germany shoots on that assumption. Nevertheless, echo sounders did not prevent many skippers from having to land large quantities of unwanted pilchards from this fishery in November 1951.

On the California research vessel *N.B. Scofield* a considerable number of small "pips" were observed in a generalized horizon of the depth recording ; they were first disregarded, but after further analysis, it was decided to adjust the trolling gear to the indicated depth. Salmon were taken almost immediately, where very few fish had been taken at other depths. Commercial trollers were informed and after changing the depth they also began to catch fish. In some instances the echo sounder indicated salmon "pips" moving about in a thin cloud or smudge, which has been interpreted as a dispersed shoal of herring or other small species on which the larger fish were feeding (Echo Sounders... 1950). Southern California sardine and mackerel fishermen have found that they can distinguish with marked accuracy between the echo records from shoals of sardines, mackerel and anchovies. Sardines show a solid wide flash of light on the indicating sounder. On tape, mackerel traces seem to be striated with a peculiar ribbed appearance. Anchovies are said to produce echoes with comparatively weak and broken flashes.

(*f*) THE PRODUCTION OF A FISH TRACE

To understand the possibilities in echo sounding, it is necessary to know the physical characteristics of the sounder and the reflecting qualities in the fish. There are five factors mainly concerned in the production of an echo trace as recorded on paper. The first is that large fish produces a bigger and stronger signal than as mall one and hat the appropriate size dimension for this comparison is probably he horizontal cross sectional area of the fish. Experiments carried ut in Lake Windermere in the English Lake District (Cushing and ichardson, in press) on dead fish hung below an echo sounder have hown that the returned signal from cod is about nine times stronger han that from herring, which is roughly in proportion to the areas of heir horizontal cross sections. The second result from this series of xperiments concerns the presence, or absence, of an air bladder. An ir-water boundary is an almost perfect reflector for sound transmitted n water ; fish-air boundaries will be a little less sharp. It was found hat 40 percent of the returned signal could be attributed to the air ladder which takes up 5°_{0} of the volume of the fish ; artificial air ladders were hung alongside the fish to ascertain this fact. This xplains why the records obtained from mackerel are so thin as compared with those from herring or pilchard, for the mackerel have no ir bladder. A third result from the Windermere series of experiments as that an approximately linear relation was obtained between the trength of returned signals and the number of fish on the axis of the ound beam. The difference between the herring and the pilchard races is one of color, that is, the black pilchard trace means a much tronger returned signal. It is thus possible that the difference between hese two traces is a difference between densities of shoal. The fourth esult from this series of experiments concerns the effect of the frequency. The stronger returned signal is probably to be expected when he dorsiventral dimension of the fish approximates to the wavelength. This applies to the air bladders too, so at one frequency, differences etween signals may be a function of the size of the fish and the size f its air bladder. The last and most important factor in the producion of a trace is the size of the shoal as indicated above; here it must e pointed out that this effect will vary with the directional character f the sounder. Thus, a large shoal in the narrow sound beam of a ighly directional sounder, giving a plume shaped trace, gives a comet trace in the wide beam of a less directional sounder. Summarized, the five factors involved in the production of a trace are the :

(1) size of the fish ;
(2) presence, shape and size of the air bladder;
(3) shoaling density of the fish ;
(4) size of the fish in relation to the frequency of the sounder ;
(5) size of the shoal in relation to the spread of the beam angle of the sound.

Ultrasonic frequencies used in echo sounding are not directed only in a narrow, straight vertical beam ; the sound " envelope " is more or less drop-shaped. In simplified form the shape first resembles a cone, then a cylinder, and finally at great depths, a reversed section of a cone. The reason is that echoes from the sides are weaker in deeper water and are lost : therefore the sounder does not record the full width at greater depths. The width of the sound area at the bottom is, on an average, one-third of the water depth. It is impossible to know the size of the fishes from the darkness or thickness of the recordings. As depth increases, a greater extent of amplification becomes necessary and different amounts of power must be used for various depths.

As the sound describes more or less a cone, an object over which the sounder moves slowly will first appear on the edge of the cone, then in the middle and lastly at the opposite side. At the sides the distance to the vessel is longer than in the middle ; therefore, the recording will show the object as if it first were deeper, then higher, and then deeper again. Balls of 20 cm. (8 in.) diameter, placed in the water, were recorded as being 5 m. (16.4ft.) high. Herring models were run over with the echo sounder and were indicated as 2 m. high. It was investigated how near single fish must be in order to be recorded as a shoal. At 15 m. (49.2 ft.) depth and 10 m. (32.8 ft.) distance from each other, the models were clearly shown separately. In deeper water, they were only clearly shown if they were 15 or 20 m. (49.2 or 65.5 ft.) apart. Models set apart at one depth will be separated when the difference in range of the models from the oscillator amounts to one wavelength or more. This means that in deep water possibly a few single fish can give indications similar to those caused by a shoal but of low intensity.

In another test, 24, 15 and 20 fish models were so distributed on an area 10 x 10 m. (32.8 x 32.8 ft.) at 23 m. (75.4 ft.) depth, that the distance between them was 2, 2.5 and 3 m. (6.6, 8.2 and 98 ft.) The result showed that the fish must be at least 2.5 m. (8.2 ft.) from each other to appear separately on the recording. One conclusion is that some failures when fishing for shoals which appeared on the recording might be due to recordings of single fish not very far apart.

In the flashing type or non-recording echo sounders there are similar problems. The signs are, for example, not as wide in deeper water with the same degree of amplification (Brandt and Schärfe, 1950).

(*g*) FISH BEHAVIOR

The echo sounder is an instrument that might have been specially designed for the study of fish behavior. A continuous vertical migration of fish was first shown and published by Runnström (1941) and later by Tester (1943) — a solid layer slowly climbing from the bottom to the surface. Recently this was repeated for sprat by Richardson (in press).

Diurnal migrations have been shown by comparing the night and day depths of a number of shoals. This has been done pictorially throughout one night by Schüler (1951). A diurnal rhythm has been established for a number of shoals over many nights by Richardson (in press) for Shields and East Anglian herring. In extension of this work he has related the movement of the shoals to the depth of light penetration, and has found that herring make a dawn rise before descending to day depths in their optimum band of light intensity.

Analogous to the work on vertical migration of fish and its relation to light intensity is the work on the effects of artificial lights on

sh shoals. Hodgson and Richardson (1949) showed quite clearly that
lchard shoals, after a first shock reaction, rise slowly towards a light
ung over the side of a ship. Schüler and Krefft (1951) lowered a
) watt underwater lamp down to 30 m.; in 4 out of 5 cases when
ne lamp was switched on, the fish shoals exhibited the shock reaction.

i) Scattering Layer

An account of fish behavior would be incomplete without refer-
ice to the scattering layer. This is a vertically migrating layer giving
diffused echo that extends for many miles in shallow and oceanic
aters. Non-migrant parts appear (Dietz 1948; Tchernia 1950), re-
ersed migrations take place (Hersey and Moore, 1948) and there are
ften multiple layers. A shallow scattering layer had been identified
ı the English Channel as consisting of young fish, in the main pilchards,
nat have just acquired their air bladders (Burd and Lee, 1951). Hersey
nd Moore (1948), Moore (1950), and Boden (1950) produced evidence
hat the unidentified deep scattering layer in the Atlantic and Pacific
ceans may consist of euphausids. Tucker (1951) has demonstrated
hat many forms of deep water fish live in the layer; Marshall (1951)
as produced cogent reasons for this interpretation. Because of the
epth of water and the fact that the identification of pelagic fish in
eep waters is difficult, the problem is a hard one. Sounders have
een operated since the war in seas rich in plankton, including eupha-
ids, with no record. The Windermere series of experiments showed
hat a single cod could be picked up at 30 fathoms, but only faintly.

i) Use of Horizontally-mounted Echo Sounder

Some attempts have been made to use the ordinary echo sounder
or locating fish in a horizontal direction by mounting the transducer
n the side of the ship. Such experiments have, for instance, been
arried out in Japan by Mr. Hashimoto (Japan, Fisheries Agency, 1951),
ısing a 24 kc. wet paper recorder. He found that:

(1) an echo sounder transmitting in a horizontal direction can tell the position of fish within an error of 2^0;

(2) with the transducer in a horizontal direction, an effective beam of 30^0 is obtained for locating fish;

(3) in rough water the record is disturbed by the ultrasonic sound waves reflected by the sea surface: in less than 10.93 fathoms of water, fish detection is disturbed by sound waves reflected by the sea bottom;

(4) the proper dip angle of the transducer is 5^0 to 10^0.

(j) Installation of Transducer

Much thought has been given to the proper installation of the
ransducer on the hull of ships, but disturbances to the ultrasonic
sound waves caused by the form, trim and speed of the ship still present
nany problems.

The problem is relatively easily solved in the case of passenge vessels and other ships with constant loading conditions. Difficultie of a more complex nature are encountered with installations on ship with variable trim such as fishing boats. Here the bubble layer forme round the hull in the light load condition frequently affects the sensitivity of the apparatus through absorption of sound waves. This ca sometimes be remedied by having the transducer projecting from th hull. Another installation problem frequently is the permeation los caused by the ship's bottom plate. The transducer is usually place in a tank filled with fresh water, which is fixed to the bottom plate i the case of steel vessels. When the ultrasonic waves are transmitte through steel plate, they are considerably attenuated. This permeatio loss can sometimes be reduced substantially by using an oil mediu instead of fresh water. The application of some anti-corrosion an insulation paints can also seriously reduce the electro-acoustical efficiency of the apparatus, and great care should be taken in their selection and application (Japan, Fisheries Agency, 1951).

(*k*) TRENDS OF DEVELOPMENT

This brings us back to the beginning : the relation between fisheries and the echo sounder. This review has described the use of th sounder in the fisheries at the moment, and the meaning of the mar on the paper has been discussed in terms of the fish in the sea. Th potential use of the echo sounder is likely to develop in two directions The first is in research into the nature of the record, much of whic is carried out by the fishermen themselves. Fisheries scientists ar likely to be concerned with the accurate measurement of signals returned from identified fish, with the proper estimation of shoal densitie and shoal sizes, with the acoustic impedances of fish material, with th distribution of signals within a sounding and the proper identificatio of fish traces. The makers of commercial sounders are likely to b concerned with improvements in the fisherman's sounder. Sounder in use in Lowestoft, England, during the last three years have double or trebled their power outputs as compared to the older ones, hav increased the range of amplification, have been transmitting throug thinner plates and have operated on various frequencies ; these ar the types of alteration to the navigational sounder that are likely t take place. The appearance of the German Fischlupe has raised th question of the most appropriate form of presentation. The Fischlup has a cathode ray presentation, which is detailed and sensitive. I lacks, however, the memory of a paper recorder. The Fischlupe possesses one very great advantage : it uses no paper and, as this cost about £ 1 sterling for a roll of 10 yards, the operation of this sounde becomes much less expensive than its competitors. It would be a great advantage also to know the minimum paper speed for an optimu beam angle that would allow identification through comparison of successive soundings on the paper. A recent German model combine the use of a cathode ray with a paper recorder in one apparatus. Th ond is in the development of the fisheries. It is possible that the st important advance is yet to come in the use of echo sounders l Asdic or Sonar with pelagic trawls or purse seines. When pelagic wls can be made to work reliably in the open sea, this development, conjunction with echo survey and radio, will make the exploitation pelagic stocks the most efficient possible.

Echo Ranging

In 1950, the new modern Norwegian research vessel *G.O. Sars* s commissioned. This vessel has been fitted with Asdic in addition the usual echo sounding equipment. The principle on which Asdic l Sonar works is similar to that employed in echo sounding but where- the echo sounding oscillators are fixed in the hull of the ship and nsmit sound waves which are reflected by the bottom of the sea. dic oscillators are atable and the im- lses are transmitted rizontally in any en direction. A oal of fish, therefore, uld only be located echo sounding if e vessel were direct- above it, whereas, dic equipment would able the shoal to be ated at a range of to 2,500 yards from e vessel, along a e of bearing.

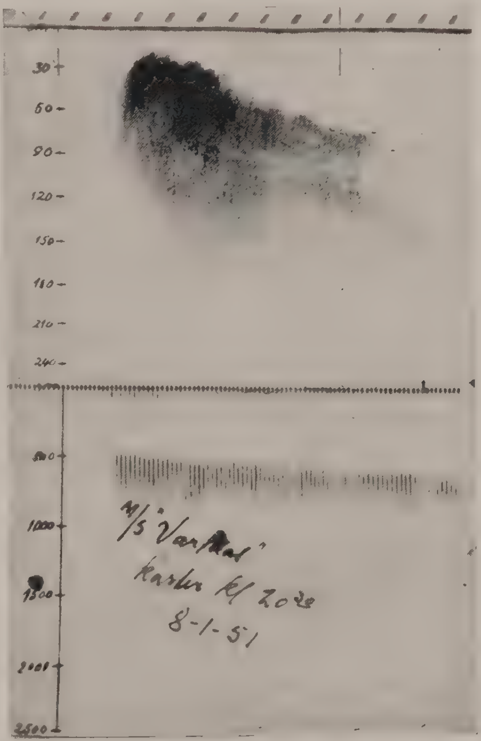

Figure 7. The upper photo shows the registration of a herring shoal by echo sounder ; the lower one the registration of the same shoal by Asdic. The scale is given in meters.

In the summer of 50, *G.O. Sars* located ge concentrations of rring north of the roes. Later in the mmer, the herring oved northwards, eping to the east of e cold water masses ich constitute the ith-going East Ice- dic Arctic Current. rresponding obser- tions were made dur- the summer of 1951. The fishermen were ormed about the rring concentrations located in the open sea, but in 1950 they would not leave the well-kno fishing grounds off Iceland. The fishing off Iceland that sumn was very poor, and at the close of the season five vessels went to Jan Mayen area, a trip which resulted in very good catches. In 19 the fishing off north Iceland also appeared to be poor. When *G.O. Sars* reported that she had registered large concentrations of herr 80 to 130 nautical miles east of Iceland, the fishing fleet acted advice from the vessel. In the course of 3 weeks, 100 vessels cau herring valued at N. Kr. 7.000.000 in the area to which they had b directed.

From the experience gained on the two summer cruises w *G.O. Sars* it can be said, without much doubt, that it will be possi in future summers to locate the herring in the Norwegian Sea. It now also beyond doubt that the fishing fleet will take notice of reports they receive from the research vessel. A pelagic herring fish in the Norwegian Sea has thereby become a reality.

Work on the question of finding which routes the herring follov on their spawning migration to the Norwegian coast was taken up w the use of Asdic. The importance of solving this problem is obvi when it is realized that in some years about 20,000 fishermen mi

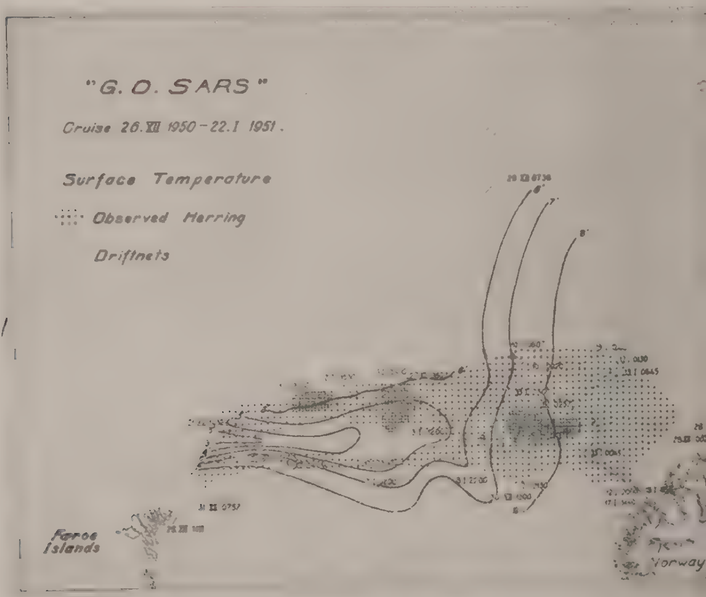

Figure 8. Surface temperatures were taken by the *G. O. Sars* in December 1 in an attempt to establish that herring live in cold water during the winter. diagram shows surface temperatures, herring shoals located by Asdic, and locat of driftnets.

dle for a whole month awaiting the arrival of the herring in coastal ers. Russian investigations on the Murman coast seemed to inte that herring lived in cold water during the winter. If mature ing were also to be found in the cold water during winter, it was onable to assume that herring shoals would follow the East Icelan- Arctic Current as far as it extended towards the Norwegian coast. December 1950, a cruise was made with the *G.O. Sars* to try this othesis. By taking hydrographic sections in the relevant areas, positions of the isotherms were determined, whereby the extent he cold water could be established. Herring shoals were located Asdic in the cold water, and the *G.O. Sars* was able to keep con- with the shoals for the last 300 miles of their migration to the wegian coast. In the winter of 1951/52 a similar cruise was car- out, with the same results. The fishermen received daily reports the positions of the herring shoals, and when the shoals came hin reach, the fleet went as far as 50 nautical miles out to sea start fishing. In a day and a half about 40,000 tons of herring e caught, having a first sale value considerably above what it had t to build and equip the *G.O. Sars*. It can be concluded that in coming years Asdic will be as necessary an instrument for the wegian fisherman and fisheries biologist as the echo sounder is ay.

Aerial Scouting

Among the most unique uses of aircraft is that of increasing the ch of marine fishes by aerial scouting. The advantages of aerial uting over that from the mast-head of a ship are threefold :

(1) a greater area can be scouted during a given period of time ;

(2) a greater area can be scouted at a given instant, owing to the greater height of the observer above the sea surface ;

(3) sub-surface shoals are more readily visible than they would be from a ship.

The first record of aerial fish scouting is in the western Atlantic nhaden fishery in 1920 (Harrison 1931). The method was apparently ccessful but, for some reason or other, was not put into general ctice.

In 1930, a program of aerial scouting was initiated in the Ice- dic herring fishery and has been carried on regularly since then, cept for a period (1932-37) when no planes were available. During last six years two planes have searched the waters off the north ast (as far as 100 miles out) during the summer herring season. The rial survey is financed and operated by the fishing industry on a -operative basis.

Whenever weather permits, the planes systematically scan large eas of sea. Usually an experienced skipper acts as observer and when herring shoals are spotted the fishing fleet is informed of th location by radio-telephone.

The Icelandic herring fleet tends to congregate in rather limite areas where the skippers believe the herring will come to the surfac This limits the fleet's searching efficiency materially and the fisherme seem to rely to a great extent on the aerial scouting service to alert ther when herring starts shoaling on the surface in distant areas. Aeria scouting is all the more important because echo sounding is still foun to be of very limited value in fishing off the north coast of Iceland whe purse seines are used for catching herring which shoals on the surfac Feeding on small crustaceans which migrate vertically, herring in thes waters are extremely excitable and "wild," shoaling on the surfac one moment moving at considerable speed and then submerging suddenly

Aerial scouting has also been used in Norwegian herring fishing t some extent.

In recent years the use of planes has come into prominence in th tuna fishery of the east-central Pacific, which is carried out largel by the so-called tuna clippers or live bait boats. These vessels are admirably adapted for carryng planes by virtue of the free space aft over the bait tank. It is doubtful if purse seiners could carry a plane owing to space limitations. About 28 of the larger clippers now carr planes as standard equipment. These are single engine monoplanes equipped with floats, which cost about $5,000.

One helicopter has been used and found to be superior to the mono planes because it can be used in rough weather and brought aboar by the pilot. Launching or retrieving monoplanes requires the service of the major part of crew and they cannot be used in rough weather Unfortunately, available helicopters cost about $25,000 ; a price whic precludes their use. According to Dr. W. M. Chapman, Director o Research, American Tunaboat Association, "... the airplane is considere by the fleet now to be of only marginal profit. A cheap helicopter ma change this considerably." Other estimates have been made whic indicate that the increase in catch more than pays for the helicopter i one year. If these estimates are accurate, it is difficult to understan why helicopters are not in general use by the fleet.

In practice, the planes are used primarily for locating shoals o tuna to which the clippers can be directed by radio. They are used t a lesser extent in locating shoals of bait fishes.

Fishermen claim that they can spot porpoise shoals up to 3 mile (5.6. km.) from the beach and about 7 miles (13 km.) from the crow's nest. However, a helicopter pilot saw boats pass by a large shoa within 2 to 2½ miles (3.7 to 4.6 km.) on 3 occasions under fairly goo visibility. Large porpoise shoals can be spotted from the helicopter u to 15 miles (27.8 km.) under favorable conditions and at least 7 mile (13 km.) under poor conditions. The helicopter can fly over the shoa and check the bird activity, content of tuna, size and compactnes shoal, speed and direction, etc. Bait may even be thrown out and response of the fish checked (Helicopter used... 1950).

Aerial scouting has been done in other fisheries along the west ist of the United States. These instances have not involved opera- ns at a considerable distance from land and therefore the use of con- ntional land-based planes has been feasible. The most notable ex- ple of such scouting was in the Washington pilchard fishery, before it fishery failed. This fishery was carried out in the daytime and it s possible to locate shoals from the air and successfully direct the ning boats to them. No information on the actual value of this uting service is available, but it was continued for several years.

On the other hand, Sette (1949) felt that the method was not sible for locating pilchard off southern California. His finding is nplicated by the fact that the scouting was done by day and the ning by night.

James Squire, now of the California Department of Fish and Game, rried out aerial scouting for pilchard on a small scale off southern lifornia. In this instance he found that while he was able to locate oals of fish more readily than were individuals in surface craft, the st of the operation was not absorbed by the resulting catch of fish cept on occasions when the shoals were extremely scarce and might t be located at all from the fishing boat. He was able to distinguish tween shoals of pilchard and anchovy. One early major defect of s operation which had to be corrected was the lack of radio communi- tion between plane and ship. Mr. Squire also states that some rial scouting for pilchard, sea bass, and mackerel has been done near ieneme, California.

A rather unique combination of aerial scouting and fishing is that und in the basking shark fishery at Pismo Beach, California (Fitch, 48). The sharks are located, usualy within one mile off shore, from air. Then a DUKW (an amphibious vehicle), from which they harpooned, proceeds along the beach to a point opposite the sharks d goes out through the surf.

Scouting for pilchard has also been done from blimps off San Fran- co. This was only carried out for a brief period and was not very ccessful. Shoals of fish were seen, but their specific identity was certain.

Regular air spotting of menhaden was done successfully during the 49 season. One Piper Cub plane was engaged for 18 vessels. It ually flew at 1,000 ft. (305 m), from which height the shoals are sible for miles. From a crow's nest of a vessel they can be seen only to a distance of a few hundred feet. Fish submerged to 20 ft. (6.1) are visible from a plane but invisible from surface craft. Fish other an menhaden also surface in shoals. The pilot claimed that he often uld determine the species by the colors in the shoals. (Planes prove... 50).

The preceding examples have all pertained to the use of aerial scout- as an aid toward an immediate increase in the total catch of fishes.

An indirect application is found in the use of aerial scouting by fisherie
biologists as an aid in exploratory and biological work.

According to Blackburn and Tubb (1950), aerial scouting has bee
used in Australian waters in exploratory work. They state tha
these aerial observations "... were mainly intended to indicate broadl
the general patterns of geographical and seasonal distribution of th
various pelagic fish, which could then be checked and filled in deta
by the boat surveys." This work was intended to obtain knowledg
of the resources of a rather large area, such knowledge being a primar
requisite to the exploitation of the resources.

Aerial scouting has also been used by biologists in attempts t
obtain estimates of population sizes. The example of pilchard scoutin
off southern California mentioned above (Sette, 1949) was intende
for this purpose. As noted, it was unsuccessful.

An ingenious use of this technique, described by Kelez (1947
has been the use of aerial photographs as a basis for estimating th

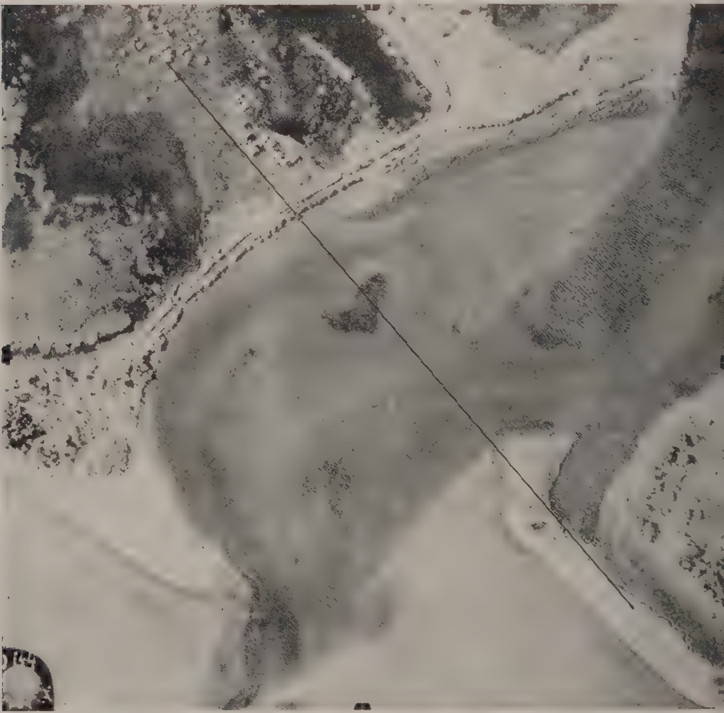

Figure 9. Photograph of red salmon at the mouth of Brooks River, Alaska. Take
from an elevation of 1,000 ft. (305 m.) on 2 September 1947. An estimated 1,60
salmon are shown between the oblique line and the river mouth. (Official Unite
States Fish and Wildlife Service photo by George Eicher).

umbers of salmon spawning in the rivers and lakes of western Alaska. y this method large areas can be covered rapidly and a permanent cord is secured. Subsequent examination of such photographs nder magnification permits fairly reliable counts to be made. An ex-mple of such a photograph is given in Figure 9. From this photograph is estimated that there are 1,600 salmon between the superimposed blique line and the mouth of the river.By making photographic rveys of selected key areas each year, relative changes in the size the spawning stock may be followed.

The potentialities of aerial scouting for fishes are rather difficult assess. Full realization of the potentialities will, of course, depend pon the initial, operational and maintenance costs of aircraft as com-ared to the increase in value of the catch brought about by aerial scout-g. The ratio between these two could be made more favorable in two ays : first, by having a fleet of vessels, rather than only one, served by a ngle aircraft. This system is used in Iceland and was successfully sed in the Washington pilchard fishery ; it should be feasible in any shery where the potential fishing grounds grounds are relatively large nd where the individual shoals tend to occur in supershoals or shoal roups, rather than to occur uniformly or at random over the fishing rounds. Second, where a plane is used by each ship, the initial and ther cost could be reduced. An example of this is found in the American una fishery, as mentioned above. This practice has apparently been f marginal or doubtful value owing to the fact that fishermen have ad to use planes designed for other purposes and which were conse-uently inefficient for their use.

Reportedly, a low-cost helicopter is in design, but is not yet on ne market. This plane is supposed to sell for about one-fifth the cost f available helicopters, or at about the same cost as the conventional ionoplanes now in use.

According to Coward (1950), a plane designed specifically for use y the tuna fleet should have the following characteristics :

"1. Ease of handling with ships' gear with no special care equired to launch and recover the airplane — must be able to withstand harp drops into the water and a lurching, sharp recovery in hoisting board the tuna boat.

" 2. Quick take-off performance even in moderate seas without anger of structural damage.

"3. Corrosion-resistance to the point where inspection and main-enance for corrosion is no particularly severe problem.

"4. Low initial and operation cost."

Although such a plane does not now exist, he estimates that a ionoplane could be produced whose initial and operating costs would e much lower than that of the planes now being used.

Aside from cost considerations, there are at least two additional roblems which may be encountered in aerial scouting for fishes. One f these involves the identification of species sighted. In many areas several species of shoaling fishes may occur and mistaken identificatio of the shoals might, in the case of a purse seiner for example, mean th difference between a profitable trip or a "skunk" trip with many hour of work removing gilled fish from the net. Presumably, the problem o identification could be easily solved by experienced fishermen.

The other problem is that of judging the depth of sub-surface shoal which is apparently rather difficult visually. Perhaps this problem ca be solved electronically.

The use of aerial scouting as a research tool has been little investigated. The potentialities may be greatest in this field.

D. H. Cushing, Finn Devold,
John C. Marr, and H. Kristjonsso

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STABILIMENTO TIPOGRAFICO FAUSTO FAILLI — ROMA

Oyster Condition Affected By Attached Mussels

By James B. Engle and Charles R. Chapman
Chesapeake Shellfish Investigations
U. S. Fish and Wildlife Service
Annapolis, Maryland

STER production has declined
naterially since the turn of the
ary. On the basis of government
stics, the only figures of nation-
ope available, the present yield
out one-third of what it was in
irst decade of the twentieth cen-
(Table I.)

oduction in the years prior to
undoubtedly demonstrated ex-
ation of a vast accumulation of
tural resource. Efforts to main-
the high yield pushed the capaci-
f the natural population beyond
ability to reproduce the stock,
e the decline. Losses, cumulative
ne natural population, are more
e as the stock becomes smaller.
must attempt to control the
ces of these losses, due in part
redatory and competitory ani-
, mortalities from changing con-
ns such as flooding, silting and
amination, and man-caused de-
tion of bottoms. To some extent
ave accomplished a measure of
f in isolated instances. Efforts
e combined research team of fed-
state and private interests have
een sufficient, however, to plug
he holes draining this resource,
y because fingers are too few
we have been unable to investi-
all the leaks sufficiently.

TABLE I
STER PRODUCTION IN THE UNITED STATES*

— 149	million	pounds	of	meats
— 183	“	“	“	“
— 234	“	“	“	“
— 152	“	“	“	“
— 95	“	“	“	“
— 93	“	“	“	“
— 89	“	“	“	“
— 75	“	“	“	“
— 75	“	“	“	“
— 76	“	“	“	“
— 80	“	“	“	“
— 79	“	“	“	“
— 78	“	“	“	“

ishery Statistics of the U. S. and
ka, U. S. Fish and Wildlife Serv-
Washington, D. C.

Observe Condition

At the Chesapeake Shellfish Investigations Station we have observed the condition of oysters and the causes of its variation. In Maryland and in many other areas oysters must compete with mussels (*Brachiedentus recurvus* in Maryland) for food and space. The question in our minds was to what extent this competition affected the condition and therefore the yield of oysters. Oysters with large clumps of mussels attached were poorer than those free of mussels taken from the same location. Fat oysters produce more pounds of meat than do lean ones. The measurement of the difference is the theme of this report. Our observations were conducted in two parts.

(1) Oysters were collected at two-week intervals over a period of six months from mussel infested oyster bars and divided into two groups, according to the amount of mussels attached. Those heavily covered were used as one group, and those free of mussels as the other. Comparison of these groups proceeded as follows: physical characteristics of size, shape and cavity volume; meat condition determined by per cent solids, per cent glycogen on a dry basis; and the condition factor, a ratio between amount of meat and cavity volume.

(2) When the preceding observations established the existence of a difference, an experiment was designed to test the permanence of the difference when the attached mussels were removed. The same methods of analysis were used as in (1).

Results Show

The results of these observations demonstrated the extent of the differences. Physically, oysters with mussels attached were generally larger, more elongate and contained larger shell cavities. The difference in size was not great, about 1.5 centimeters; the difference in cavity volume, also small, was about 12.5 cubic centimeters. The ratio of length to width pointed out a more significant difference and indicated the elongation characteristic of mussel-covered oysters. These oysters had a ratio of width over length of 0.67 while mussel-free oysters had a ratio of 0.75. Elongation was usually caused by a deformity at the bill or posterior end of the oyster away from the main cluster of mussels. Irregularity in shape in itself made this oyster less desirable commercially because of added difficulty in shucking. Other detrimental effects of mussels attached to oysters will be discussed later in this paper.

Tangible Evidence

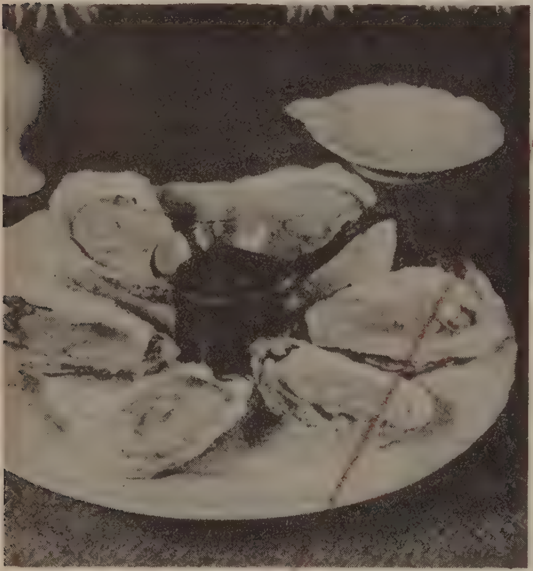
Analysis of the meats of these two groups of oysters gave more tangible evidence of the effect of mussels on oysters. Considering first the total solids produced, a difference, constant over the six months, amounted to 12.8 per cent. From this we conclude that more meat is produced from mussel-free oysters. As a measure of quality we examined the total glycogen content of these oysters. Glycogen determines the "fatness" of oysters, and in these two groups the difference was 11.1 per cent favoring the mussel-free oysters. From this we say that mussel-covered oysters have a lower nutritive value. A third index of meat value, the "condition factor," is of direct interest to producers because it shows the variation in yield of meats per unit of shell stock. Mussel-free oysters on this basis were 27.5 per cent better than those with mussels attached. (Table II.)

To indicate the effect of mussel masses on the condition of oyster meats may, at first glance, appear to be more academic than practical. We went a step further and examined oysters from which mussels were removed to see how permanent the differences were. Oysters with attached mussels were collected, the mussels removed and a series of observations made to see if the oysters thus freed wait for it to go bad before we concern ourselves; we seem to take it for granted when demand is good.

It will save a lot of last minute head-scratching and desperate props, such as price cutting, if we look after demand as we do our boats—not just sometimes, but as a steady, daily thing. If the demand disappears, then all the care we give our boats will be useless.

Too often we forget that our whole existence depends on the vital sale to a consumer. We give the important task of speaking to the consumer to someone who is out of our control—a retailer or a restaurant man. Doesn't it make sense that we control the success of our business a little better by speaking directly to the consumer who can make or break us?

Leaders in the oyster and seafood industry are well acquainted with the importance of the consumer sale. They have led the fight for greater all-industry effort in this regard. It is singular that the bigger the business man the more keenly he appreciates the importance of consumer-demand efforts like the Oyster Institute's campaign.



Few foods can boast the versatility of the oyster. Highly nutritious, it can be cooked in a number of ways, or served raw on the half-shell as pictured here. The sauce is blended of one cup of catsup, two tablespoons of vinegar, one each of horseradish, minced celery, minced onion, and Worcestershire sauce, and a few drops of Tabasco sauce and salt.

If you doubt the importance of the sale to the consumer, just imagine what would happen to your oysters or seafood if no one cared to buy them.

We oyster people certainly have a product to be proud of. Oysters are more nearly balanced nutritionally than any other food. If something is lacking in fats and starches, that makes them all the more attractive to those who are concerned about their weight—and doctors say most people today are overweight. Combined with milk as in an oyster stew, it has just about everything—even glycogen, which is called a pre-digested starch, yielding the value of starch but not the fat. Vitamins A, B, C, D, and G abound in oysters. And they are heavy in minerals and elements such as iron, copper, calcium, phosphorus, magnesium—and iodine, that great item unique to seafood.

It is small wonder that our oysters are such a rich food. They grow in waters adjoining the land from which is washed down all the vital elements needed for life. The oysters act as a sponge and take up this wealth of life-giving material which would be lost to human beings otherwise.

Scientists are still finding out things about food. While the whole of food knowledge is not known, there is no doubt that some great benefits obtained by eating all of an animal are now missing in modern life. Of course, oysters are eaten entirely and thus yield some great benefit not fully explored.

Those who have been at our oyster conventions in the last two years have been amazed at the great number of newspaper clippings, magazine articles, reports of radio and television shows, and other items gathered in the oyster publicity campaign which reach just about everyone in the country who can read, listen, or see. Last year the head of the ice industry's public relations effort said that a half million dollars worth of results were hung on the walls of the huge room where the oyster publicity was displayed. We spared him the shock of learning that we actually spent pennies where he thought we used dollars.

There is no magic to how this has been accomplished on a tiny budget—unless skill, sound judgment, and perseverance are magic. In the many years I have been connected with industry-wide promotional efforts, I have heard of money wasted—and I have seen great returns from very little expended. When publicity is utilized, ingenuity is primary, for most times you use that in place of money.

A master in getting publicity results on a national scale, A. E. Kessler, who had headed the Fishery Council effort before going into the armed services, was named our public relations counsel and his office housed our information bureau. As an ex-*New York Times* by-line reporter and feature writer, Mr. Kessler knows exactly what the press requires—a most vital consideration in this work. The soundness of his actions and policies are apparent to anyone who knows national publicity. His long association with the seafood industry has given him an insight into and fondness for the industry unmatched by any in his field.

The work of the Oyster Information Bureau is to supply the national press, radio, and telivision with timely, accurate, and interesting material on oysters.

It has been my good fortune to see a great many opera-

(Continued on Page 64)

Television has proved to be one of the most valuable mediums for oyster promotion. Here chairman Royal Toner, left, of the Institute's Public Relations Committee talks oysters with Herb Sheldon on Sheldon's popular NBC television show.

could recover the ad- ey lost over those original- mussels. The cleaned oys- ut overboard in trays with mussel-free animals. The were periodically checked e manner as those in the discussed earlier in this he results of this experi- s follows:

TABLE II
FIELD STUDY CONDITION OF OYSTERS

Shell Cavity in cc.		Per Cent Solids		Per Cent Glycogen		Condition Factor	
Oysters covered with Mussels	Oysters free of Mussels	Oysters covered with Mussels	Oysters free of Mussels	Oysters covered with Mussels	Oysters free of Mussels	Oysters covered with Mussels	Oysters free of Mussels
40.6	32.4	14.81	17.53	29.67	33.32	6.79	10.03
47.8	34.8	17.44	19.66	27.90	32.03	8.03	10.81
49.0	35.6	17.41	18.74	33.67	35.37	8.83	11.10
48.2	38.0	14.82	16.24	33.77	37.78	7.17	10.35
47.8	35.4	13.38	14.58	27.10	30.75	5.85	8.43
50.5	32.8	13.70	17.06	31.20	37.22	6.43	9.45
49.8	41.4	16.14	20.04	22.67	25.21	7.61	9.85
48.2	35.8	15.43	17.69	29.43	33.10	7.24	10.01

Average Difference Shell Cavity = 12.4
Average Difference Per Cent Solids = 2.26
Average Difference Per Cent Glycogen = 3.67
Average Difference Condition Factor = 2.76

material change occurred ape, size or cavity volume sters during the six-week

Changes Noted

the condition of the meats, progressive changes were sters with attached mussels inning of the period had a olids of 13.38 and those free 14.58. At the end of two re was no improvement fol- e removal of mussels. But d of four weeks the two oysters showed about the cent solids or 16.77 for oys- mussels removed and 16.63 s free of mussels. After at the end of the experi- ters with mussels removed per cent solids of 17.80 and 17.71. Oysters in the field s same period showed a per at the start of 13.38, af- eeks 13.70, and at the close xperimental period of six 4. These figures were com- the same time with mussel- ers in the field and gave 06 and 20.04, respectively, that no relative difference in the field.

With the experimental groups the per cent glycogen also showed a trend similar to per cent solids. At the beginning of the period the per cent glycogen of oysters with mussels removed was 27.10 and of oysters originally free of mussels 30.75. Two weeks later the per cent glycogen was 35.94 and 41.25, respectively. At four weeks the per cent glycogen was 33.76 and 35.25, and at six weeks when the experiment was concluded the per cent glycogen was 25.41 and 25.61. Oysters in the field collected and analyzed at the same intervals maintained the same difference in per cent glycogen from the start to the end of the experimental period.

Improvement

The improvement in the condition of the meats was again demonstrated by the condition factor index. The difference existing at the start of the experimental period was 2.58; in two weeks no improvement occurred, the difference in C. F. being 3.91; at four weeks the difference was reduced to 1.36; and at the end of the sixth week it was further reduced to 1.09. In the field, condition factors for the above intervals of examination maintained the same difference from start to finish of about 2.76—plus or minus —0.5 (Table III).

Summary

These two series of observations, one on the oysters in the field exposed to a natural condition where they compete with mussels and the other on a group of oysters where this competition has been removed have been analyzed to show the effect of the competition on the oysters. The results are summarized as follows:

1. Oysters covered .with mussels have poorer meats than those free of mussels.
2. When mussels are removed from these oysters they recover in four weeks to the same condition of per cent solids and per cent glycogen as the oysters originally free of mussels.
3. Mussel-covered oysters in the field have 27.5 per cent less meat per animal than those free of mussels on the basis of condition factor.
4. In the experiment this difference dropped to 10 per cent in six weeks

(Continued on Page 69)

The picture below shows a group examining a dredgeload of bottom material to estimate oyster age, distribution, fouling organism, and predators. The members clockwise from left, are: Fred Seiling, Chesapeake Biological Laboratory; Jay D. Andrews, Virginia Fisheries Laboratory; James B. Engle, chief, Chesapeake Shellfish Investigations; H. H. Whaley, Chesapeake Bay Institute.

yster Condition

(Continued from Page 29)

the trend still approaching ality.

Mussel-covered oysters tend to be irregular in shape and therefore more difficult to shuck.

All investigators should have the prerogative of speculation based on the results of experiments and observations. We feel that the yield in pounds or pints of oyster meats may be increased in a region like Maryland, where many acres of oyster bottom are heavily infested with mussels. This increase is possible without increasing the number of oysters present if the mussels are destroyed in time on the beds. We demonstrated this in our experiments.

Methods and equipment for accomplishing the destruction of mussels are in our plans and on our drawing boards at the present time, and the attempt to demonstrate the economic feasibility in the field is on our program of research for the near future.

The FWS research vessel "Alosa" used in Chesapeake shellfish investigations.

TABLE III

NDITION EXPERIMENT WITH OYSTERS CLEANED OF MUSSELS

te	Shell Cavity in cc.		Per Cent Solids		Per Cent Glycogen		Condition Factor	
	Oysters with Mussels removed	Oysters originally free of Mussels	Oysters with Mussels removed	Oysters originally free of Mussels	Oysters with Mussels removed	Oysters originally free of Mussels	Oysters with Mussels removed	Oysters originally free of Mussels
'16/51	47.8	35.4	13.38	14.58	27.10	30.75	5.85	8.43
'30/51	53.0	39.3	14.36	16.00	35.94	41.25	4.65	8.56
'14/51	47.0	39.5	16.77	16.63	33.76	35.25	8.91	10.27
'28/51	46.8	41.0	17.80	17.71	25.41	25.61	9.25	10.34

FIELD STUDY CONDITION OF OYSTERS

te	Shell Cavity in cc.		Per Cent Solids		Per Cent Glycogen		Condition Factor	
	Oysters covered with Mussels	Oysters free of Mussels	Oysters covered with Mussels	Oysters free of Mussels	Oysters covered with Mussels	Oysters free of Mussels	Oysters covered with Mussels	Oysters free of Mussels
/16/51	47.8	35.4	13.38	14.58	27.10	30.75	5.85	8.43
/14/51	50.5	32.8	13.70	17.06	31.20	37.22	6.43	9.45
/28/51	49.8	41.4	16.14	20.04	22.67	25.21	7.61	9.85

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FISHERIES INSTITUTE

Fourth Annual Session

Early Explorations in the Gulf of Mexico

PAUL S. GALTSOFF, *Fish & Wildlife Service, Woods Hole, Mass.*

History of early explorations in the Gulf of Mexico has a particular appeal the persons engaged in the present studies of the oceanography and biology f this body of water. Thrilling descriptions of the adventures of the earlier xplorers not only contain the records of their accomplishments and frequent ilures but provide also an understanding of the personalities of the principal ctors of the New World drama. From the yellowish and musty pages of e old books and maps arise live human beings who, poorly equipped but ith great courage and determination, went to explore the unknown lands eyond the vast expanse of the western ocean. Their characters and the mo- ves behind their heroic actions become understandable; and one is tempted compare their lives and the conditions under which they labored with the resent situations of scientists engaged in a study of problems of grave na- onal importance.

Political and economic rivalry mong the countries of western Europe during e sixteenth and seventeenth centuries was so acute that their successful pene- ation into the wilderness of the New World, establishment of colonies, and ccess to gold, silver, and other riches of the new continent had profound ffects on their destinies.

The beginning of the explorations in which the adventurers of Spain, Por- ugal, France, and England competed and frequently fought with each other r the possession of new territories can be formally dated back to the first oyage of Columbus.

The existence of the large sea called, at present, the Gulf of Mexico was nown, however, to the natives long before the white man set foot on the ewly discovered land. Aztecs of Mexico and natives of Yucatan were able sail considerable distances from the mainland. Some of them mastered the rt of map making to a fairly high degree of perfection. It is known, for nstance, that in 1520 Montezuma presented Cortez with a map painted on henequin cloth in which were marked rivers and bays of the northern coast f the Gulf from Panuco to Tobasco, a distance of about 140 leagues. In uly 1502, sailing south from Cuba toward Honduras parallel to the eastern oast of Yucatan, Columbus encountered an Indian vessel of the size of a panish galley with 25 men in her crew. The ship, laden with various goods nd products, was sighted 150 nautical miles from the coast of Cuba and bout 79 miles off the Yucatan coast. Had Columbus followed the Indian hip he would soon have discovered the Yucatan and found the route to

Mexico. He sailed south and east, however, believing that this course would lead him to Cathay, the name by which China was known to medieval Europe.

The first discoverer of the Gulf of Mexico cannot be positively named, since the records of the early European explorations in the Gulf are confusing and frequently contradictory. The year of the European explorations in the Gulf naturally begins with the voyages of Columbus. In June 1494, during his second voyage, Columbus followed the southern shores of Cuba as far as Isla de Pinos and, disregarding the information received from the Indians that the end of the island was not far, he decided that Cuba was not an Island but a part of a continent and sailed eastward. In this way, his opportunity of discovering the Gulf was lost.

First claim for sailing along the southern and eastern coasts of the new continent for a distance of 870 leagues (probably as far north as Cape Hatteras) was made by the man whose name is forever associated with America. Amerigo Vespucci, the third son of a Florentine notary was born March 9, 1451. He studied diligently and became quite proficient in astronomy and in the use of astrolabe, but his principal interest was in a commercial career. He established himself as an agent for the House of Cadiz, and in 1495, after the death of Juanito Berardi who contracted to supply 12 vessels of 900 tons each to the crown of Spain, Vespucci undertook to settle the claims left after his friend's death and to complete the equipment of ships. In 1497, at the request of the king, he joined the expedition to the New World. As he says in his own words, "the king, Don Fernando of Castile, being about to dispatch four ships to discover new lands toward the west, I was chosen to aid in making discovery" (Thacher, 1896, p. 69). He never explained his exact duties aboard the ship, but judging by his previous experience and excellent acquaintance wth commercal methods he probably went as a sort of supercargo to supervise the distribution of food, to weigh the gold, and to keep accurate tally of the crown's share which, according to the royal decree of 1495, was one-third of the total gold obtained by the expeditions. A rather informal description of the first voyage of Vespucci is contained in his letters written in Italian to his friend. The text was later translated and published in Latin.

The expedition sailed on May 10, 1497, from Cadiz and made a landfall, probably off the coast of Honduras in the vicinity of Caba Gracios a Dios. From this point it sailed along the coast, and after a bloody encounter with the natives in the Campeche region the ships reached the province of Lariab. In the Latin translation the place is called Parias, a mistake which caused great confusion and dispute since it lead many to believe that Vespucci referred to the Gulf of Paria off the Venezuela coast discovered by Columbus in 1498 during his third voyage. The informal style of Vespucci's narrative and obscure meaning of several of his statements induced many to believe that his claims were false and that he never even had participated in the voyages he had described (Humboldt, 1837). Others, however, gave him full credit for his achievements. His letters sounded sufficiently convincing to the group of cartographers who worked in the small village of Saint-Die in Lorraine. In about 1507, in recognition of his achievements, they decided to give the name "America" to the continent of the New World (see Martin Waldseemüller map of 1520 and Leonardo de Vinci map of 1512). The controversery about the role of Amerigo Vespucci in geographical discoveries in the New World continued for centuries. Some of his critics of more recent years maintain that Spaniards had never discovered the Gulf which very likely was visited first by the Portuguese captains who landed on its coast shortly before the year 1500. The true role of Amerigo Vespucci in the discovery of the New World probably never will be determined with certainty. It is significant, however, that the so-called Cantino map, executed in Lisbon between December 1501 and October 1502 contained the data which were described by Vespucci in his letters. This chart shows Cuba as an island, and the northwestern continental land is plainly shown from the southern point of Florida to the Hudson River. Likewise, Vespucci's discoveries are clearly depicted by Waldseemüller in a map of 1507 printed in Ptolemy Geography in 1513. As Thacher (1896) states, "Surely some ship sailed to the south of Cuba into the Gulf of Mexico around the point of Florida and well up the northeast coast before the beginning of the sixteenth century. No one ever claimed to have done these things except Amerigo Vespucci."

Tales of fabulous riches in the new land, of gold and precious stones, told by the crews of the earliest explorers upon their return to Spain stimulated feverish activities. During the first quarter of the sixteenth century large numbers of expeditions were outfitted and sailed westward. Science played only a minor part in these undertakings. The governments sponsoring the expeditions were interested primarily in the conquest of new territories, in establishing new colonies, and increasing their revenues by imposing high taxes on gold, silver, and precious stones brought back from the New World. Explorers and adventurers successful in obtaining royal decrees authorizing their enterprise were looking for a quick personal enrichment and glorification. It was customary that each expedition be accompanied by an astronomer cosmographer or cartographer to help in navigation and to record the observations needed for the preparation of maps. The duties of these men were not clearly defined, their work was frequently ridiculed and they suffered from the lack of understanding and even open contempt of the crews.

It is impossible in a brief review, to summarize the results of the principal expeditions which visited the Gulf of Mexico during the first half of the sixteenth century. For the purpose of this paper, it is sufficient to mention that in 1513, Ponce de Leon, after making a formal discovery of Florida, found the Florida Keys which he called Las Islas de los Martires and the Tortugas Islands.

In 1516, Diego Miruelo undertook another expedition to Florida, while Fernando de Cordova and Antonio de Alaminos explored the northern and western coasts of Yucatan and reached Campeche Bay. In 1518, Juan de Grijalva, in command of a force consisting of 4 ships and 250 men, retraced Cordova's route toward Yucatan, discovered Cozumel Island which he named Isla de Santa Cruz, and explored the western coast of the Gulf as far as Panuco. During this expedition the Spaniards for the first time heard the name Mexico applied to this part of the new continent. In 1519, Hernando Cortes, with Antonio de Alaminos as chief pilot, explored the same coast again and established the town of Vera Cruz while Alonzo Alvarez Pineda explored the northern coast of the Gulf and discovered the mouth of the Mississippi River which he called Rio del Espiritu Santo. Ill-fated expeditions of Panfilio de Narvaez in 1527 and of his successor, Cabeza de Vaca, explored the west coast of Florida, including Tampa Bay and the northern coast of the Gulf from Apalache Bay, and Apalachicola River (which the Spaniards called Rio de Magdelena) to the Mississippi River. The largest adventure of this type was the expedition of De Soto who assembled 7 ships with about 700 soldiers and in 1538 sailed from Havana to Florida. The discovery of Pensacola Bay, the convincing evidence that the Mississippi is a mighty stream which drains from a large continent, and the exploration of the northern coast of the Gulf, from Florida to Mexico, were the principal scientific results of De Soto's expedition. The conquest of Mexico by Cortes and the completion of the De Soto explorations marked the end of the period of earliest discoveries in the Gulf.

The Spanish government and the educated portion of the Spanish nation realized the great advantages derived from the possession of the newly acquired territories. Ability and resources to develop them were insufficient, however, but Spain jealously watched the efforts of other powers to establish colonies in America. Maps, astronomical observations, sailing directions, and other scientific products of explorations were carefully guarded. Using the modern expression, it can be said that all scientific data of earlier explorations were "classified." It was forbidden to disclose them to foreign powers. Cartographers and navigators of that time often found themselves in a difficult situation when in possession of material sought by an unfriendly power.

Realizing the importance of new geographical discoveries, the Spanish government formed in January 20, 1503, an office called Casa de la Contratracion de las Indias which functioned as a peculiar combination of the board of trade and a hydrographic office, established with special reference to regulate the commerce and navigation in the New World. The Casa had a separate department of geography and cosmography which was established in 1508 to exercise control over the charting of the newly discovered territories. For this purpose, the government ordered the preparation of a master chart, Padron Real, the completion of which was entrusted to such famous navigators as Amerigo Vespucci, Juan Diaz de Solis, and Vincente Pinzon. Official marine charts were considered of such great importance that they were kept secret, under lock in the coffer with two keys, one for Pilot-Major and one for Cosmographer-Major of the Casa. At the same time, the Spanish government issued an order prohibiting foreigners to hold the rank of pilot or mate on any Spanish ships. These attempts to prevent the dissemination of geographical knowledge confronted the astronomers and cartographers with a predicament familiar, at the present time, to scientists engaged in classified research. By the order of the government, all pilots were enjoined to trace on their charts "every land, island, bay, harbor, and other things new and worthy of being noted," and to turn over the charts to the Pilot-Major as soon as their ships landed in Spain. They could use only official copies of the government charts verified by the officials of the Casa. In this way rigid governmental control was exercised over the publication and sale of charts.

Data turned in by the pilots were not too accurate, the errors being particularly great in the determination of the longitude. As a matter of fact, scientific cartography became possible only in the middle of the seventeenth century when in 1657, Huygens built the first reliable pendulum clock, and this timekeeping instrument together with the telescope were adopted for astronomical observations. The determination of longitude was the weakest part of sixteenth century navigation. Navigational instruments of that time were few and simple They consisted of an astrolabe, astronomical ring, and cross staff or back staff the latter being crude forerunners of the modern sextant. The latitude was determined with fairly good accuracy, the error being about 1 degree, but for the determination of longitude the pilot was dependent on dead reckoning made with the traverse board on which the ship's daily speed and course was set. The crude methods sometimes led to fantastic errors and caused many uments between the principal maritime powers. The situation became the irce of grave disputes when Pope Alexander VI, issued, in 1943, the Bull of marcation. The purpose of this masterpiece of diplomacy was to settle ims of the two rivals, Spain and Portugal, by assigning to the first one "all ds not already belonging to any other Christian prince which had been or uld be discovered 100 leagues west of the meridian line passing through the ores," and to Portugal all the discoveries east of this line. The catch was at nobody knew the position of the line.

During the fifteenth and sixteenth centuries, the trade in maps and charts veloped as a highly specialized profession. The cartographer was a learned an—proficient in astronomy and navigation and a skillful draftsman. He was o an artist, experienced engraver, and printer. Information needed for the nstruction of a new map was coming to him from various sources—frequently uggled from abroad or obtained by other illicit means. His fate was not vays a happy one, especially if he permitted himself to get mixed with litics or involved in a controversy about religious dogmas. Mercator, ose name is forever associated with navigational charts and map projec-n, was one of the foremost cartographers of the sixteenth century who, ring the 57 years of map making, perhaps did more than any other man elevate cartography from a low art to the position of exact science. One of s maps made in 1538 for the first time applied the name "America" to both e North and South American continents. In 1544, he hardly escaped from ing burned at the stake when, by the order of the Regent Mary, Queen owager of Hungary, he was seized as an heretic, and with 43 others con-mned to death. The campaign against Lutheran heresies at that time was nducted with such violence that the only restraint against wholesale slaugh- was the consideration that the provinces should not be entirely depopu-ed. Men of science had to watch their words and actions very carefully order to avoid the clutches of the inquisition. The conditions under which ey worked remind us of the present situation of thousands of scientists oring behind the Iron Curtain and forced, under the continuous threat their lives, to conform their findings to the principle of Marxian doctrine interpreted by the politbureau in Kremlin.

The position of a cosmographer or astronomer attached to various ex-ditions was a peculiar one. The undertakings were of a definitely military ture. Large forces, sometimes comprising several hundred foot soldiers and rsemen, were assembled. Ships were loaded with weapons, food, various pplies, and sundry materials for establishing colonies. Large dogs, mostly eyhounds and mastiffs, trained for battle, were taken in large numbers and ed in fighting the Indians and guarding camps. In the conquest of the New orld, these dogs accomplished great feats and won the admiration of Span-rds, who recorded in their annals the names of the most celebrated ani-als. The greatest strength of the invaders consisted, however, in horses. The ght of an unknown, large animal, protected by heavy leather covering which tended down to its knees and mounted by heavily armed horsemen, was rifying to the Indians until they learned the technique of incapacitating the rses by shooting arrows into their knees. The effect of cavalry attacks on dians during these expeditions was probably similar to the effects of first acks of tanks on the army entirely unprepared to oppose the new weapon. om the commentaries of Cabeza de Vaca or from the history of the De to expedition written by Garcilaso de la Vega so-called "The Inca" we arn about the efforts of the men who while participating in the military operations at the same time were engaged in astronomical observations, s veyed the coast, and recorded the nature of the country, listed its plants a animals, determined its suitability for colonization, and described the custo of its natives. Frequently these duties were combined with the functions o government representative assigned to the expedition. Thus, the De S expedition was accompanied by Juan de Añasco who as a comptroller His Majesty Imperial Exchequer was looking after the interests of the Span treasury. According to Gracilaso, he was also a "cavalier," a great marin cosmographer, and astrologer." He brought back documented reports regard the coastline, harbors, anchorages, and observations on mineral riches, a fertility of the country. How little support this man received from his co panions may be judged from an incident described by Gracilaso. Toward end of the De Soto expedition, after the death of its leader and the loss in at Mobile of all the instruments for navigation, the survivors managed to bu several small canoes in which they escaped from the pursuing Indians. A leaving the mouth of the Mississippi River, they sailed westward, travel near the coast. Añasco, being a resourceful man, managed to salvage an ast labe which because it was made from metal was only slightly damaged by f From a parchment of deerskin he made a sea chart, and with a ruler, he c structed a forestaff. These crude instruments were of great help in guiding boats, but his companions ridiculed him so for his efforts that in disgust threw all the instruments overboard.

Sometimes the expeditions were accompanied by artists who made picto records of the country and its people. Probably the most interesting do ments of that type were made by LeMoyne in 1564, an artist who accompan the French expedition to Florida under Laudonniere. Fortunately, the orig drawings depicting the life of Florida Indians, excellently reproduced in heliotypes published in 1825, are now available for study together with translation from the original Latin text.

Records of the ealiest explorations of the Gulf open up an interesting ture of a slow and uncertain progress of scientific research conducted un the most difficult conditions by men of great determination and unfai energy. Bits of scientfic knowledge gained during these efforts, scattered unsystematized as they were during the first half of the sixteenth cent eventually were brought together and correctly evaluated. They helped to f a sound basis of the present geography of the Gulf. The cosmographers explorers of that time often found themselves in the possession of informa which was of great inportance to the government and the disclosure of wh to a foreign power would be regarded as treason. As at the present time, attempts to keep scientific data confined to state boundaries completely fa proving that they cannot be kept secret indefinitely. In studying the record the earliest explorations, one cannot fail to have high respect and admira for the explorers and scientists of the old time whose determination and sourcefulness laid the foundation of our present geographic knowledge.

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Staining of Growth Rings in the Vertebrae of Tuna
(*Thunnus thynnus*)

Paul S. Galtsoff

tebra, and otolith of the plaice published by Heincke (*op. cit.*) seem to corroborate his conclusion.

Heincke and Immerman used the following technique: Bones were separated by cooking and soft tissues removed by gentle maceration. Following this, the bones were treated, first with "strong" (95°?) and then with absolute ethyl alcohol, and were defatted in benzine and ether. Drying in air completed the procedure. In certain cases, clarification in glycerine revealed the growth rings with greater clearness than could be attained in dry specimens.

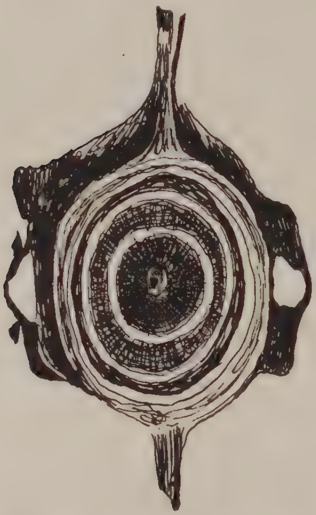

Fig. 1. Caudal vertebra of tuna, alizarin stain, from a fish 104.5 cm. long, weighing 50 lbs. Actual dimension of the vertical diameter of the centrum is 2.2 cm. Drawn from a photograph.

Other authors who studied this problem in perch and codfish suggested the use of diluted writing ink (violet), rubber stamp ink, and picrocarmine in order to disclose the finest rings in small and thin scales and opercula of these fishes. It was claimed by Winge and Nilsson that picrocarmine produces differential staining of bones, the old deposits staining yellow, the new ones, pink.

In a study of material consisting of dried vertebrae of tuna fish, *Thunnus thynnus* (Linnaeus), collected during the summer of 1950 by the Fish and Wildlife Service in Cape Cod Bay, I failed to obtain satisfactory results with these methods. It was therefore necessary to develop a different staining technique which would make the growth rings clearly visible.[1]

The selection of the method used was based on the following considerations. It is known that some of the dyes of the anthraquinone group (alizarins) can be successfully used for gross staining of skeletons and for determining the presence of insoluble calcium salts in the cell contents. Lippman (1935) has shown that alizarin Red S is a specific stain for bone, and Hollister (1934) found that there is a great affinity of this dye to calcium phosphate, and that certain correlation exists between the intensity of staining and the concentration of this salt in the bone. It appeared, therefore, promising to try the alizarin method for revealing the growth rings in the vertebrae of tuna. The results (Fig. 1) fully justified this assumption. After several trials with various solutions I found that the following technique gave the best results:

Material and Method.—Dry vertebrae cut from fish bodies preserved in 10 percent formalin; soft tissues removed.

1. Rinse in distilled water.
2. Keep in 4 percent potassium hydroxide from 24 hours to 3–4 days depending on the size of the specimen. Prolonged treatment in KOH solution renders the preparation fragile.
3. Place in about 200 ml. of 0.1 percent alizarin stock solution in 2 percent potassium hydroxide for 24 hours or longer, at room temperature. Alizarin stock solution is prepared according to the following formula of Hollister:

Alizarin Red S, saturated solution in 50 percent glacial acetic acid	5 ml.
Glycerine, c.p., white	10 ml.
Chloral hydrate, cryst., 1% aq. sol.	60 ml.

4. Rinse in water. Place in 4 percent potassium hydroxide for 12 to 48 hours.
5. Place in a mixture of 2 percent potassium hydroxide solution containing 40 percent of white glycerine for 1–2 days.
6. Increase the glycerine content to 80 percent. Keep 1–2 days.
7. Place in pure glycerine, change after 24 hours.
8. Place in fresh glycerine. Mount in glass jar.

Defattening of preparations in benzine or ether, preparatory to staining, was found to be unnecessary.

Since growth rings of the vertebrae are confined to the surface lining of the vertebra, the preparation should be very carefully andled during the dissecting and processing o avoid injury to the periosteum and underying tissue.

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[1] The use of the term "growth rings" in this article does not imply that the circles revealed by staining are "annuli," for proof that the rings are laid down one per year is lacking.

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ICHTHYOLOGY. -*Eight new fishes from the Gulf coast of the United States, wit two new genera and notes on geographic distribution.* Isaac Ginsburg, U. Fish and Wildlife Service. (Communicated by Ernest A. Lachner.)

In the course of my studies of the fishes of the Gulf of Mexico, eight species were found not to have been named previously. This conclusion was reached after a virtual revision of the species of their respective families that occur in the Gulf and adjacent waters. Only one of the species is based on a single specimen. The others are based on sufficient numbers to indicate that they are not uncommon. Three of them are common enough to enter the commercial fish catch at the present time. One offshore species apparently occurs in sufficient numbers to have market possibilities.

During an investigation of the southern species of commercial shrimps, the U. S. Fish and Wildlife Service, by means of the research boat *Pelican*, preserved and brought together a collection of fishes on the coast of our Southern States, which is of great value in the study of the ichthyological fauna of the Gulf and adjacent waters. It is my privilege to be engaged in a study this collection, and four of the species herei described were obtained by the *Pelican*.

Three of the species indicate a peculiarit of geographic distribution of the fish faun of the Gulf, to which attention is called an which is discussed at a later point.

The photographs for Figs. 1–8 were mad in the Smithsonian Photographic Labor tory.

Family SERRANIDAE

Centropristes melanus, n. sp.

Gulf Black Seabass

D X 11. A III 7. P 17–18. Sc 47–49.

Dorsal and anal spines and rays constant 12 specimens). Gill rakers on lower limb 10– with 1–4 tubercles, or 14–17 altogether; on upp limb gill rakers grade gradually into tubercles the difference between the two kinds only mo erately indicated, 7 or 8 altogether; total numb of gill rakers and tubercles on both limbs 21–

dy elongate, moderately deep. Mouth termi- l, lower jaw subequal to upper in front or ghtly projecting. Maxillary ending under mid- of eye or posterior margin of pupil, without pplemental bone; a broad, rather shallow elon- te groove below upper maxillary edge, setting an elongate, moderately depressed piece hav- g somewhat the shape of a supplemental maxil- ry (as in *Epinephelus*), but without an evident ture. Teeth in jaws in bands of medium width, idest in upper jaw; side of lower jaw with only o rows of teeth; outer and inner teeth mod- ately enlarged; no canines; none of the teeth epressible to a marked extent. Opercle drawn it posteriorly to form a rather long, flexible ap; middle opercular spine well developed; lower ine moderate; upper spine not developed, in rm of blunt, rounded protuberance. Preopercle ot expanded; its transverse margin well serrate; wer margin rather sparsely serrate, the serrae overed by skin; serrae at angle slightly enlarged; teropercle and subopercle moderately serrate or nooth. Branchiostegal rays 7. Scalation on mid- ack ceasing at moderate distance behind eye, s anterior boundary a nearly straight, trans- erse line; cheek and opercle scaled; interopercle parsely scaled; patch of scales over cheek and percle moderately or rather well separated from osterior scales; interorbital, snout, suborbital, axillary and lower jaw naked; proximal part of audal rather well scaled for a considerable dis- ance, scaleless posteriorly; other fins scantily caled near their base; all scales ctenoid (besides mall scales on fins), except those on chest some- imes cycloid. Lateral line moderately rising an- eriorly, running nearly parallel to contour of ack and at some distance below it, making a light curve at caudal peduncle; 4 or 5 longitu- linal rows of complete scales between highest art of lateral line and midback, besides a row of ncomplete scales; modified, channeled scales in ateral line moderately smaller than adjacent ormal scales, not separated by latter or only lightly so. First three dorsal spines abruptly and early evenly or somewhat unevenly graduated; irst and second usually about half as long as econd and third, respectively; third spine only little shorter than fourth and longest; thence ery gradually decreasing in length to eighth; ast two spines subequal to or slightly longer than he one immediately preceding; last spine moderately shorter than first ray, emargination be- ween spinous and soft parts of dorsal moderate. Second anal spine a little shorter and slightly stouter than third. Ventral about reaching anus or falling a little short, its outer angle a little in front of lower pectoral angle. Pectoral having its posterior margin nearly truncate, rounded at angles, more so below than above, ending nearly on same vertical as ventral or a little behind. Caudal asymmetrical, rounded for its greater and lower part, a moderate emargination above, the second branched ray from top moderately or slightly produced.

Measurements of four specimens 95–136 mm in standard length, and two, including the holotype, 177–206 mm, expressed as a percentage of the standard length, the ranges of the smaller specimens in parenthesis, as follows: Depth (33.0–38.5) 35–36, depth of peduncle (13.5–14.5) 13–13.5, head to end of flap (40–41.5) 41–44, maxillary (17–18.5) 20.5–21, snout (11.5–12.5) 12.5–13, eye (8.5–9.5) 8–9, interorbital (7–8.5) 7.5.

General ground color dark to nearly black; often with very faint traces of irregular, wide darker cross areas, separated by narrower, slightly lighter interspaces; scales with a lighter colored area on exposed part anteriorly, surrounded peripherally with dark pigment, presenting in gross appearance effect of beadlike longitudinal lines of light spots along rows of scales; no definite dark spot at posterior end of spinous dorsal base; a diffusely dusky area on inner side of opercle, at its upper, anterior part, but no well-defined spot on inner or outer surface of opercle; anal and ventral dark, sometimes edged with lighter color; pectoral uniformly very moderately dusky or nearly pigmentless; dorsal with obliquely lengthwise rows of diffuse light spots; caudal with very faint spots, almost uniformly dusky or dark.

Holotype.—C.N.H.M. no. 33719. Newport, near Wakulla, Fla.; November 10, 1937; Fred Ladd; 270 mm.

Paratypes.—C.N.H.M. nos. 33717–8, 33721–3; same data as holotype. Pensacola, Fla.; S. Stearns

TABLE 1.—FREQUENCY DISTRIBUTION OF THE NUMBER OF GILL RAKERS AND PECTORAL RAYS OF CENTROPRISTES MELANUS AND C. STRIATUS

Species	Total gill rakers and tubercles on both limbs								Gill rakers and tubercles on lower limb only						Pectoral rays			
	21	22	23	24	25	26	27	28	14	15	16	17	18	19	17	18	19	20
melanus	1	4	6	1	1				1	5	5	1			8	5		
striatus					8	6	15	1			1	13	14	2		8	23	1

(U.S.N.M. no. 21483). St. Marks, Fla.; B.C. Marshal; August 1931 (92232). Aucilla, Fla.; *Fish Hawk* station 7147; 3 fathoms; November 6, 1901 (73009). Cedar Keys, Fla.; C. R. Aschmeier; March 3, 1938 (106990). Total 11 paratypes 48–270 mm.

Remarks.—This species differs from the other two species of *Centropristes* occurring in the Gulf, *ocyurus* and *philadelphicus*, in having fewer scales and more gill rakers (scales 53–57 and total number of gill rakers and tubercles on both limbs 18–21 in the latter two species) and in not having the caudal biconcave, besides other minor differences. It is very close to the Atlantic *C. striatus*. As shown in Table 1, *melanus* diverges from *striatus* in the combined gill raker and tubercle count, that on the lower limb of the first gill arch and also in the total of both limbs, to a degree that is of species magnitude or very nearly so. A high divergence of the pectoral count is also indicated, but of lesser magnitude. Also, in *striatus* the emargination on the upper part of the caudal is generally more pronounced, and the second branched ray from the top is usually much more prolonged. The data for *striatus* given in Table 1 are based on specimens ranging from Woods Hole, Mass., to New Smyrna, Fla.

Three species of *Centropristes* occur in the Gulf, *melanus*, *philadelphicus*, and *ocyurus*. The species here described is the counterpart of *striatus* from the Atlantic. By their long isolation, the Gulf and Atlantic populations have diverged morphologically to a degree of species magnitude, or at least to a degree that is at the borderline of species and subspecies. I have also compared the Gulf populations of *philadelphicus* and *ocyurus* with their corresponding populations in the Atlantic and find some differences; but those differences are of low degrees, below the subspecies level. It is reasonable to assume that all the populations have been isolated by the peninsula of Florida equally in point of time. It is interesting then to note that in the same genus there is an evident wide difference in the tempo of population divergence.

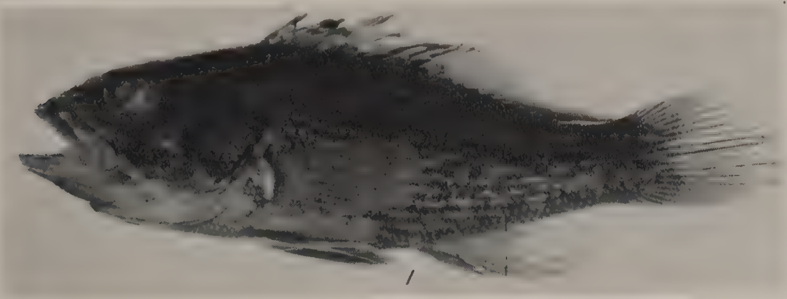
Weed (1937) treats of the species of *Centropristes* and describes a new species, *springeri*, from the Gulf. His treatment in some respects is unsatisfactory. He does not adequately describe the well-marked difference in the shape of the caudal between *striatus* and *philadelphicus*, which evidently constituted the main character on which Gill established a distinct genus, *Triloburus*, based on *philadelphicus*; but the cauda of his specimens might have been damaged. H further states that the scale count is the sam in all the species; whereas I found it to be a goo character for separating *striatus* and *melanu* from *ocyurus* and *philadelphicus*. The latter dis crepancy might be due to differences of method Weed counted the scales in the lateral line, whil my counts are of the number of oblique row above the lateral line. I have reexamined th three specimens on which Weed based his *sprin geri* and find that they belong to the same specie as the holotype of *ocyurus*, and consequentl these two names are synonymous, *ocyurus* havin priority.

Serraniculus, n. g.

Genotype.—*Serraniculus pumilio*, n. sp.

Body elongate, rather spindle-shaped. Mout subsuperior, the lower jaw moderately projecting No supplemental maxillary. Upper jaw withou notch. Teeth in jaws in rather wide bands; in tw rows on side of lower jaw; outer teeth in both jaw and inner teeth in lower jaw enlarged, a fe moderately enlarged inner teeth at symphysi of upper jaw also; inner teeth on side of lowe jaw largest, 3 or 4 of those teeth moderatel larger than adjacent ones but hardly large enoug to be designated canine; vomer and palatines wit teeth; tongue toothless. Lower two opercula spines well developed; upper spine short an pointed or a rounded, slight protuberance. Trans verse margin of preopercle serrate, lower margi smooth. Branchiostegal rays 6. Gill rakers short few. End of posttemporal not covered by skin exposed in form of rather heavy scale (ofte referred to as "axillary scale"). Body entirel covered with ctenoid scales, including chest an pectoral base; opercle and cheek scaled; inter opercle scaled for a variable distance at it posterior end only; dorsal aspect of occipu interorbital, snout, suborbital, maxillary an lower jaw scaleless. Lateral line rising moder ately in front and making a slight curve at cauda peduncle; three longitudinal rows of complet scales between highest part of lateral line an midback, besides a row of incomplete scales modified, channeled scales in lateral line notabl smaller than adjacent normal scales and separate by them. All dorsal spines pungent and of norma length. Caudal having its distal margin ver slightly rounded.

This genus is near *Centropristes*, structurall and in general appearance. *Serraniculus* differ constantly having six branchiostegal rays, stead of seven. The caudal shape is as in the ung of *Centropristes* and markedly unlike that the adults. That is, *Serraniculus* retains the venile caudal of *Centropristes* also in the adult ge. *Serraniculus* differs as well from all other own serranid genera on the Atlantic coast of North America in having six branchiostegal rays. As errors in the treatment of this character have entered the literature, which have been copied and repeated by successive authors, the pertinent literature of the species concerned is here briefly reviewed in connection with the establishment of *Serraniculus*.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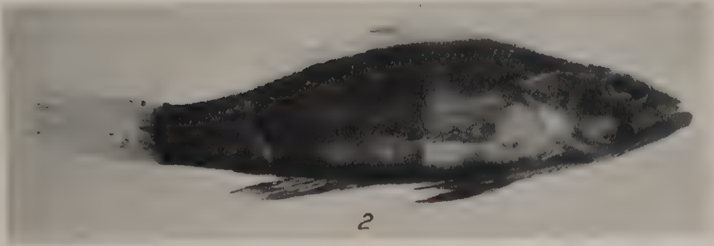
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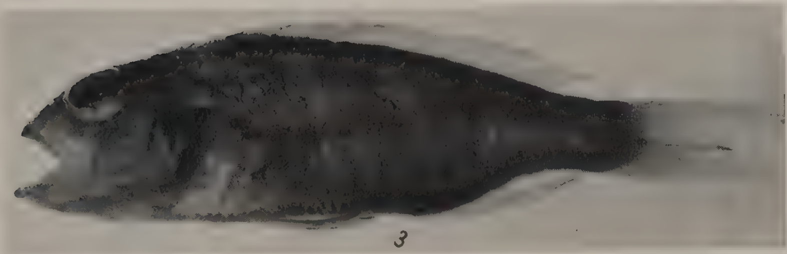
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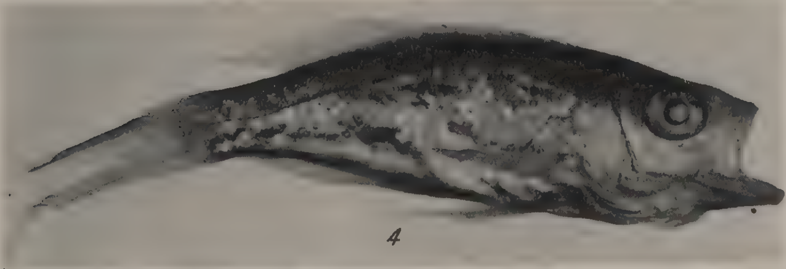
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FIGS. 1-4. 1, *Centropristes melanus*, n. sp., a paratype, 122 mm; 2, *Serraniculus pumilio*, n. gen. and ., holotype; 3, *Paracentropristes pomospilus*, n. sp., holotype; 4, *Anthiasicus leptus*, n. gen. and sp., olotype.

Jordan and Evermann (1896, pp. 1218–1219) erroneously place *Centropristes subligarius* Cope and *C. dispilurus* Günther in *Dules* Cuvier on the assumption that they have six branchiostegal rays. However, in 21 and 5 specimens of those two species, respectively, which I examined in the National Museum, the branchiostegal rays are constantly seven. Also, in those two species the dorsal spines are normal in length and pungency, none being notably produced. *Dules*, on the other hand, is a monotypic genus characterized by a combination of two salient characters, the presence of only six branchiostegal rays and the striking whiplike prolongation and flexibility of the third dorsal spine. These two characters hold in all 14 specimens of what is presumably *Dules auriga* Cuvier, which I examined in the National Museum from the general region of Río de la Plata, South America. *Serraniculus* has six branchiostegal rays like *Dules*; but otherwise the two genera seem only remotely related. *Dules* differs from *Serraniculus*, apart from the structure of the third dorsal spine, in having a notably deeper body, a long, somewhat pointed snout, a deeper and shorter caudal peduncle and more numerous dorsal rays, the latter often being a generic character in the family Serranidae.

Boulenger (1895, p. 287) erroneously placed *subligarius* and *dispilurus* as synonyms of *Dules auriga*, claiming that the former two names represent females and the latter name males of the same species. Judged by his listed specimens, Boulenger evidently examined only three specimens, one *auriga*, two *dispilurus* and none of *subligarius*, and based his sex determination and conclusion on these three specimens. In reality, these three names represent three separate species which are very readily distinguishable, much more so than some other closely related serranid species.

Fowler (1907, p. 265) establishes a new subgenus, *Callidulus*, under *Dules* (which he renames *Eudulus*), based on *subligarius* as the genotype, again on the erroneous assumption that *subligarius* has six branchiostegal rays. The new name *Callidulus* (as well as *Eudulus*) is an unnecessary addition to the nomenclature, as *subligarius* is near enough to *Serranus scriba* Linnaeus to be placed in the same genus; while *scriba* is the genotype of *Serranellus* Jordan (in Jordan and Eigenmann, 1890, p. 399). Therefore, *subligarius*, and the closely related *dispilurus*, should be placed in the genus *Serranellus*. On a revision of the family, it might be found advantageous to treat *Serranellus* as a subgenus of *Serranus*, as it was treated by Jordan and Eigenmann.

The untenable placement of *subligarius* and *dispilurus* by Jordan and Evermann and their erroneous treatment by Boulenger are perhaps due, in part, to the three species having two general features in common: (1) the shape is rather unusual and similar in all three species, and (2) they also have a light yellowish color more or less developed in the abdominal region. Either these features represent parallel developments in *Dules auriga* or else the latter is derived from *Serranellus* but has become modified to such an extent as to represent a divergence of genus magnitude.

The five specimens of *dispilurus* which I examined, as noted above, so labeled in the National Museum collection, evidently correctly, are from Jamaica and Puerto Rico. Jordan and Eigenmann (1890, p. 405) venture the opinion that *dispilurus* is a synonym of *Dules flaviventris*, which Cuvier and Valenciennes (1829, p. 113) originally described from Brazil. Judged by the brief description of the latter species, the suggested synonymy seems well advised; but I have no specimens from Brazil to verify it. Should that synonymy prove to be correct, then Cuvier and Valenciennes were also in error in placing *flaviventris* in *Dules*, as they based that genus, first established in the publication cited above, on the presence of six branchiostegal rays.

The first branchiostegal ray in serranids is often short, thin, and closely approximated to the second ray, and it might be overlooked unless particular care is exercised. This perhaps explains some of these errors that entered the literature.

Serraniculus pumilio, n. sp.

D X (10) 11. A III 7. P 14–15. Sc 44–46. GR 5–7.

Dorsal rays normally 11 (in 20), infrequently 10 (in 1); dorsal and anal spines and anal rays constant (in 21). Pectoral rays 14 (in 12) or 15 (in 9). Gill rakers on lower limb 5–7 with 1–4 tubercles, or 8–11 altogether; upper limb with 0–3 gill rakers and 0–4 tubercles, or 3–5 altogether; total number of gill rakers and tubercles on both limbs of the first gill arch 11–14. Body and caudal peduncle of medium depth; upper profile rising moderately from snout to dorsa origin; peduncle deeper than eye diameter; dis-ce from a median point under end of dorsal ·audal base, greater than eye diameter; maxil- ending under anterior margin of pupil or htly behind. First three dorsal spines rapidly l almost evenly graduated; the first a little than one-half as long as second; second a le more than one-half as long as third; third fifth subequal or slightly increasing in length, nce gradually decreasing to ninth; tenth spine ttle longer than ninth and moderately shorter n first ray, emargination between spinous l soft parts of dorsal moderate. Ventral rather rt, falling short of anus, its end at a more terior point than that of pectoral, its outer gle slightly in front of lower pectoral angle, spine about one-half as long as rays. Distal rgin of upper two-thirds of pectoral a well- lined line, its lower angle rounded.

Diffusely and irregularly cross-banded; with r diffuse, dark or dusky bands, the first under rsal origin, the last at caudal base; anterior ree bands broader than interspaces, last band mparatively narrow, preceded by broad lighter erspace over greater part of caudal peduncle; e bands without definite boundaries, the dark ade more or less encroaching and becoming ffuse on interspaces; sometimes bands and in- rspaces hardly distinguishable, except light in- rspace on peduncle; interspaces often with a very tinge, the interspace between first and cond bands often especially prominent as a ansverse silvery band on lower two-thirds of dy, under middle of spinous dorsal; a series of all dark spots on upper profile often dis- nguishable, 4 or 5 at dorsal base, the first at se of last spine, the fourth or fifth at end of rsal somewhat more prominent, one at end peduncle and one or two on upper margin of udal near its base; a characteristic, yellowish, unded spot directly behind last dark band, at s lower half; sometimes a similar spot, smaller d not as well marked, also at its upper half; light streak along course of lateral line with ark very small spots placed at somewhat irregu- r intervals; spinous dorsal usually with a large ark blotch a little below its distal margin, etween seventh and ninth spines, often hardly erceptible; anterior margin of dorsal often with hree dark dots, one above the other; ventral nd anal almost uniformly dark to black; other ns usually rather sparsely pigmented, without ows of well marked spots, except some irregular hadings, and caudal and lower pectoral edge roadly margined with dusky or blackish.

Measurements (expressed as a percentage of the standard length) of three specimens 56–59 mm, including the holotype, and 3, 70–80 mm, those of the smaller specimens in parenthesis: caudal (25–26) 24–25, ventral (24–25) 22–23, pectoral (26–28.5) 26.5–28.5, depth (27–29.5) 29.5–31, depth of peduncle (12.5–13.5) 13–13.5, head (34.5–35) 35.5–36, maxillary (13–14.5) 14–15, snout (8.5–9.5) 9–10.5, eye (9.5–10) 8.5–9.5, interorbital (5–6) 5.5–6.5.

Holotype.—U. S. N. M. no. 133791. *Fish Hawk* station 7177; lat. 29° 05′ N., long. 83° 22′ 30″ W.; off Cedar Keys, Fla.; 5½ fathoms; November 27, 1901; 56 mm.

Paratypes.—Off Mobile Bay, Ala. (U.S.N.M. nos. 101521, 144164–5). Georgia (149971). Off Cape Lookout, N. C. (131015). Texas; Texas Game, Fish and Oyster Commission (C.N.H.M.). Also, the following *Pelican* stations: Off Cape Canaveral (station 208—2) and St. Augustine (208—8), Fla.; off St. Andrews Sound (177—12), St. Simon Island (178—7) and Ossabaw Island (180—7), Ga.; off Head Island (182—8), St. Helena Sound (195—2) and Edisto Island (194—13), S. C. Total paratypes 20, taken in 6–32 fathoms, 33–80 mm.

Remarks.—The abdominal cavity of one 63-mm specimen was exposed to examine the gonads. They were found to contain ripe eggs. The structure of the gonads does not appear to be uniform in gross appearance. Interspersed with the masses of ripe roe are areas of tissue which have the gross appearance of milt. It seems probable, therefore, that this species is hermaphroditic like some other serranids.

This is the smallest American serranid discovered so far. It is readily distinguished by its generic and specific characters. Its relationship is discussed above under the account of the genus.

Paracentropristes pomospilus, n. sp.

Prionodes atrobranchus Longley (not Cuvier and Valenciennes), Carnegie Inst. Washington Publ. 535:106. 1941 (Tortugas).

D X 12. A III 7. P 14–17. Sc 46–48. GR 9–11.

Dorsal and anal spines and rays constant (in 26 specimens). Pectoral rays normally 16 (only 4 variants in 57 specimens, 14 and 15 in one each, and 17 in 2). Gill rakers on lower limb 9–11, with 1–3 tubercles, or 10–13 in combined number; upper limb with 6 or 7 gill rakers and tubercles combined; total combined number of gill rakers and tubercles on both limbs 17–20. Rather spindle-shaped, depth medium; depth of caudal peduncle somewhat greater than eye diameter. Snout subequal to or slightly shorter than eye. Mouth terminal, lower jaw subequal to upper or slightly projecting. Maxillary without supplemental bone, ending approximately under middle of eye. Teeth small, in narrow bands, widest in upper jaw, in two rows on side of lower jaw; upper jaw having outer teeth and a few inner teeth at symphysis larger than others; lower jaw having a few anterior outer teeth and all teeth in inner row enlarged; some inner teeth on middle of side of lower jaw larger than all others, but not large enough to be designated canine. Opercular spines poorly developed, short, stubby or slightly pointed. Preopercle serrate; serrae on lower margin stronger than those on transverse edge, except without serrae anteriorly for a third the distance or less. Scalation on antedorsal area extending to eye and continued on interorbital space approximately to opposite posterior margin of pupil; cheek, opercle, and interopercle completely scaled; anterior part of interorbital, snout, suborbital, maxillary, and lower jaw scaleless; 3 or 4 rows of complete scales between highest part of lateral line and midback; modified, channeled scales in lateral line notably small, widely separated by adjacent normal scales. First three dorsal spines nearly evenly graduated, the second about two-thirds as long as third; fifth or sixth spine longest or the two subequal, the length very gradually decreasing to third and last spines; first ray moderately longer than last spine, emargination between spinous and soft parts of dorsal slight. Second anal spine shorter and slightly stouter than third. Ventral pointed, reaching anus or a little short. Pectoral having distal margin of its upper two-thirds in a moderately inclined line. Caudal moderately and asymmetrically lunate, the upper lobe longer.

Measurements of four specimens 114–120 mm, including the type: Caudal (upper lobe) 25.7–31.0, ventral 27.0–29.5, pectoral 29.0–32.5, depth 31–35, depth of peduncle 12.5–14.0, head 34.5–37.5, maxillary 16.0–17.5, snout 9.0–10.5, eye 11.0–11.5, interorbital 5.5–7.0.

General color a nearly uniform light brownish or yellowish; sometimes very faint indication of dusky rather narrow cross bands, in an occasional specimen a somewhat obliquely placed cross band on body under base of eighth to ninth spine fairly marked; a lengthwise row of small, light yellowish spots, subtriangular or irregular, on body behind head, a little above pectoral base, ending near end of pectoral, discernible only in the smaller specimens having the scalation nearly intact, imperceptible in the majority of specimens; some specimens with trace of a narrow black margin on anal and caudal; belly with a silvery tinge, better marked on chest; upper part of opercle with a large black or dusky area on inner surface, visible externally as a dark spot, often divided into two spots; no dorsal spot or other color marks.

Holotype.—U. S. N. M. no. 151883. *Pelican* station 108—1; lat. 28° 03′ 30″ N., long. 95° 41′ 30″ W.; off St. Joseph Island, Tex.; 26 fathoms; January 23, 1938; 120 mm.

Paratypes.—Three specimens obtained with the holotype; 29 other specimens collected by the Pelican at 19 other stations off the following localities: Padre Island and Corpus Christi, Tex.; Atchafalaya Bay, Grand Isle, and Mississippi Delta, La. Also, specimens in the National Museum taken off Dauphin Island, Ala., and Tortugas, Fla. Total number of paratypes 56, 75–133 mm. Depth records for these lots range 20–90 fathoms.

Remarks.—This species has been compared with the Mediterranean (Labrus) *Paracentropristes hepatus* (Linnaeus), the genotype of *Paracentropristes* Klunzinger. The Mediterranean species differs in having the scales 52–57, the interorbital nearly all scaled and the caudal very moderately emarginate. However, the two species are similar to a sufficient extent to be placed in the same genus. Among American species *pomospilus* is related to (Serranus) *Paracentropristes notospilus* (Longley). The two American species differ in a number of characters, the most striking of which are: the very poorly developed opercular spines of *pomospilus*, its deeper caudal peduncle, the lack of a dorsal spot and the presence of an inner opercular spot.

Longley refers specimens of this species to *Centropristes atrobranchus* Cuvier and Valenciennes. However, these authors (1829, p. 45), state that their species has a large black spot on the dorsal. Jordan (1887, p. 532) and Boulenger (1895, p. 289), both of whom examined and described the type specimen and placed the species under *Serranus*, state that it has a "jet black" and "inky black" blotch on the dorsal. In contrast, the 33 specimens recently preserved by the *Pelican* do not show a trace of such a spot, and this also holds for the other 24 specimens examined; while the presence or absence of a

sal spot is often a good specific character in
anid species. Moreover, judged by Boulenger's
cription there is another, structural difference.
states of the type of *atrobranchus*: "preopercle
ly serrated, the serrae coarser at the angle,
olete on the lower border . . . ;" while in our
cimens the serrae on the posterior two-thirds
the lower border, are well developed and as
rse as at the angle. It is evident that the
cies here described is not the same as Cuvier
l Valenciennes's *C. atrobranchus*.

Anthiasicus, n. g.

Genotype.—Anthiasicus leptus, n. sp.

Body comparatively slender. Mouth superior.
pplemental maxillary absent. Upper jaw with
moderate notch at symphysis. Teeth in jaws
narrow bands, except in a single row on side
lower jaw; outer teeth very moderately en-
ged; both jaws with two small canines in
nt and two inner canines; a caninoid on side
lower jaw; vomer and palatines with teeth;
ngue toothless. Opercular spines poorly de-
loped; the two lower ones short, obtuse; the
per not developed, a mere rounded protuber-
ce. Transverse margin of preopercle rather
ll serrate; serrae on lower margin sparse; one
rra at angle of preopercle rather large, sub-
angular; interopercle and subopercle with a
ooth edge. Gill rakers long, numerous. Bran-
iostegal rays seven. End of posttemporal not
vered by skin, exposed in form of rather heavy
ale. Scales comparatively numerous; anterior
oundary of scalation a nearly straight trans-
rse line at posterior margin of eye; interopercle
aled; interorbital, snout, suborbital, maxillary
d lower jaw scaleless. Lateral line placed at a
nsiderable distance below dorsal contour, five
ngitudinal rows of complete scales between
ghest part of lateral line and midback, besides
vo rows of smaller scales at dorsal base; modi-
ed, channeled scales in lateral line moderately
maller than adjacent normal scales and moder-
ely separated by them. All dorsal spines pun-
ent and of normal length. Pectoral pointed.
audal deeply lunate, the lobes filamentous,
early half as long as standard length.

Anthiasicus is evidently allied to the group of
rranid genera which is partly characterized by
aving numerous rather long gill rakers, in addi-
on to other characters. As compared with its
ear relatives in that group it differs from *Prono-
grammus* in the low position of lateral line and
e relatively small scales. From *Hemanthias*, it differs in having the third dorsal spine of normal length and pungency, not greatly prolonged and flexible, and in the deeply lunate caudal. From *Ocyanthias* it differs in the low position of the lateral line, the absence of teeth on the tongue, and the small scales. From *Anthias* it differs in not having the anterior part of the head scaled, in the notably shorter third dorsal spine, in the small scales, and in not having the ventrals greatly prolonged. The body is notably slenderer than in any of those genera.

Anthiasicus leptus, n. sp.

D X 14. A III 8. P 19. Sc 78. GR 10–26.

Eye rather large, subequal to snout, a little less than peduncular depth, about three times in head. Maxillary ending under anterior margin of pupil. First three dorsal spines nearly evenly and rapidly graduated, the first two-thirds as long as second, third moderately shorter than fourth and longest, thence gradually and slowly decreasing in length to last; last spine about three-fifths as long as first ray, emargination between spinous and soft parts of dorsal rather well developed; dorsal spines with very short filaments or tabs. Second anal spine moderately shorter and stouter than third. Ventral somewhat filamentous reaching a little past anal origin, its outer angle under lower pectoral angle. Pectoral reaching a vertical through vent. Color nearly uniform, golden above shading to silvery below; fins straw yellow; no distinctive color marks.

Measurements (expressed as a percentage of standard length). Standard length 108 mm; caudal upper lobe 48.5, lower lobe 46.5; ventral 28.5; pectoral 23.5; depth 31; depth of peduncle 13.5; head 36; maxillary 16.5; snout 11; eye 12; interorbital 8.5.

Holotype.—U. S. N. M. no. 134189; *Albatross* station 2378; lat. 29° 14′30″ N., long. 88° 09′ 30″ W.; off Dauphin Island, Ala.; 68 fathoms; February 11, 1885; 160 mm; the only specimen examined.

The relationship of this species is discussed above under the genus. It is easily distinguished from all known Gulf serranids by the combination of its generic and specific characters, especially its fin ray, scale and gill raker counts.

Family LUTIANIDAE

Pristipomoides andersoni, n. sp.

Pristipomoides macrothalmus Hildebrand (not Müller and Troschel), Carnegie Inst. Washington Publ. 535:120. 1941.

D X (10) 11. A III 8. P 14–16. Sc 49–53. GR 16–17.

Dorsal rays normally 11 (in 36), infrequently 10 (in 1). Dorsal and anal spines and anal rays constant (in 38). Pectoral rays modally 16 (in 20), nearly as often 15 (in 16), sometimes 14 (in 2). Gill rakers on lower limb 16 or 17 with 0–2 tubercles in 24 specimens 100–240 mm, 16–18 with 0 or 1 tubercle in 14 specimens 44–95 mm, the total number of gill rakers and tubercles in both size groups 16–18; upper limb with 7–10 gill rakers, the 2–4 near angle of arch longer and nearly evenly graduated, the upper ones more or less abruptly short, the uppermost one sometimes tubercle-like; combined number of gill rakers and tubercles on both limbs, at all sizes, 24–28. Body rather deep, well compressed, somewhat spindle-shaped, ventral curvature only moderately less than dorsal. Snout rather short, blunt, subequal to or a little longer than large eye. Interorbital flat and broad, only a little narrower than eye diameter. Mouth well inclined, terminal, lower jaw only slightly projecting. Suborbital moderately wide. Maxillary ending under anterior margin of pupil or a little behind. Teeth on jaws, vomer and palatines small, in narrow bands, except outer and inner teeth in jaws and inner teeth on vomer more or less enlarged; upper jaw having one or two outer teeth near to and on both sides of symphysis large, caninoid, the other outer teeth smaller and gradually decreasing in size posteriorly; vomerine band of teeth somewhat in form of an arch with a shallow concavity posteriorly and crowned by a blunt apex anteriorly, without a backward extension on the shaft; no teeth on tongue. Opercle having a moderate spinous projection in a line with lower margin of eye, another projection at some distance above it blunt, broadly rounded. Preopercle without or with a very slight emargination on vertical edge, its horizontal edge serrate nearly all the way forward. Interorbital scaleless, boundary of scalation on midback opposite posterior margin of eye or slightly behind; an oblique band of scales on nape over cheek and opercle, well separated from rest of scales; greater part of interopercle scaled with 2–3 rows of scales; lengthwise rows of scales above lateral line parallel to it; dorsal and anal scaleless. Dorsal spines rather slender, first three very unevenly graduated, the first about half as long as second, the second only a little shorter than third, the last subequal to second; first dorsal ray very moderately longer than last spine, soft and spinous parts of dorsal nearly continuous. Anal spines very moderately stout, the first about half as long as second, the second a little shorter than third. Last dorsal and anal ray longer than preceding rays. Ventral about reaching anus. Pectoral about reaching a vertical through base of first anal spine. Caudal deeply lunate, the upper lobe somewhat longer.

Measurements of two specimens 178–216 mm, including the type and two specimens 81–94 mm, those of the smaller specimens in parenthesis: caudal (upper lobe) 33.5–35.0 (30.0–32.5), ventral 26.0–26.5 (24.5), pectoral 31–32 (30.0–31.5), depth 37.0–40.5 (36–39), depth of peduncle 11.5 (12), head 35–38 (37.5–38.5), maxillary 16.0–16.5 (16–17), snout 11.5–12.5 (10.5–11.5), eye 10.5–11.0 (12–13), interorbital 9.5–11.5 (10.5–11.0).

General color of preserved specimens straw yellow, often with a slight reddish tinge; lower half often partly or almost wholly with a silvery tinge; often with a few very small, rounded or elongate, dark spots on lateral line spaced at irregular intervals or bunched close together, sometimes similar spots in oblique row on nape; no other distinctive color marks; fins plain yellowish. In life the species is of a prevailing pink color.

Holotype.—U. S. N. M. no. 151882. *Pelican* station 40; lat. 27° 24′ 30″ N., long. 96° 13′ W.; off Padre Island, Tex.; 90 fathoms; 216 mm.

Paratypes.—Two specimens obtained with the holotype; 27 other specimens collected by the *Pelican* at 17 stations off the following localities: Padre Island, Corpus Christi, and St. Joseph Island, Tex.; Marsh Island and Atchafalaya Bay, La.; Horn and Petit Bois Islands, Miss.; Perdido Bay and Cape San Blas, Fla. Also, specimens in the National Museum taken at Tortugas, Fla., and off Dauphin Island, Ala. Altogether 37 paratypes 44–263 mm. Depth records, available for all except two lots, range 13–95 fathoms.

This species differs from the West Indian (*Centropristes*) *Pristipomoides macrophthalmus* (Müller and Troschel) in having more gill rakers and fewer scales. In three specimens of *macrophthalmus* from Cuba, 200–350 mm, the gill rakers on the lower limb are 11–12 and 2–4 tubercles or 13–16 altogether; on upper limb 6 or 7 gill rakers and tubercles combined; total number of gill rakers and tubercles on both limbs 20–22. This compares with a total count of 24–28 in 38 specimens of *andersoni* given above. The scale count in the Cuban specimens is 55–57 as compared with 49–53 for the 38 specimens of *andersoni*.

It is a pleasure to name this apparently com- on, offshore snapper after William W. Ander- n, who, while carrying out an investigation of e species of commercial shrimp on the U. S. sh and Wildlife research boat *Pelican*, ines- nably served the science of ichthyology by dustriously saving, preserving, and assembling a unit a very valuable collection of fishes from f the Gulf and Atlantic coasts of our Southern ates.

Family SPARIDAE

Pagrus sedecim, n. sp.

D XII 9–11. A III 8. P (15) 16. Sc 56–59. R 9–11.

Dorsal and anal spines and anal rays constant n 16). Dorsal rays usually 10 (in 14), sometimes (in a specimen from North Carolina) or 11 (in specimen from Brazil). Pectoral rays normally 6, sometimes 15 (16 on both sides in 14, 15 on oth sides in one, 15 on one side and 16 on the ther in one, both variants from the Carolinas). pper limb of outer gill arch with 6 or 7 gill kers; lower limb with 9–11 including one ubercle; total number on both limbs 15–17. Ioderately deep (for a sparid); anterior profile sing steeply and making a smooth curve to orsal origin; ventral profile nearly horizontal om head to anal origin. Snout long; preorbital road; eye rather large. Mouth of medium extent, early horizontal, sub-terminal, lower jaw slightly ncluded. Maxillary reaching a vertical through nterior margin of eye in the smaller specimens, little short of that in the larger. Anterior part f jaws with a short outer row of strong, stout, early conical teeth, large enough to be designated canine, usually 4 teeth in upper jaw and in lower, the middle two teeth in lower jaw much maller than others; side of jaws with two rows f very stout, short teeth, anterior teeth in outer ow subconical, rather pointed, changing to mo- ars posteriorly, inner row shorter, the teeth all nolar; an elongate patch of smaller teeth on both ides of midline behind outer anterior teeth, nterior teeth in patch rather conical and pointed ecoming stouter and changing to small molars osteriorly; the patch of smaller teeth over- apping the two outer side rows of large teeth. Greater part of interorbital scaled, anterior bound- ry of scales curving to a point opposite anterior nargin of eye; band of scales on cheek moderate, apering upward. First four dorsal spines un- venly graduated, first nearly two-thirds as long s second; second and third about four-fifths as long as third and fourth, respectively; fourth longest, fifth subequal to it; procumbent spine absent. Second anal spine a little stouter than third, the two subequal in length. Ventral about reaching anus, its base a little behind that of pectoral. Pectoral long, falcate, reaching to over base of first to third anal spines. Caudal well lunate, upper lobe longer than lower.

Measurements of 3 specimens 366–425 mm, and two specimens 228–263 mm including the holotype, those of the smaller specimens in parentheses: Caudal (upper lobe) 29 (32.0–32.5), ventral 19.5–23.0 (23.5–24.0), pectoral 36.5–38 (35.5), depth 36.0–39.5 (38.5–40.5), head 30.5–32.5 (33.5–34.5), maxillary 13.0–13.5 (13.5), snout 13.5–16.0 (15.0), eye 7.0–7.5 (9.0–9.5), preorbital (across its greatest width, on a line oblique to axis of fish) 8.5–9.5 (9.5).

Ground color almost uniformly yellowish sometimes with a slight pinkish blush; upper half of body with many very small brownish spots, irregularly scattered above lateral line, roughly tending to an arrangement along longitudinal lines below it. The small spots are present in 4 specimens, 212–428 mm, which were preserved during the last 12 years, and absent in all others preserved for 25 years or longer. Apparently they disappear after long immersion in preservative. In life the ground color is of a reddish tinge and the spots are bluish.

Holotype.—U. S. N. M. no. 151881. 25 miles south of Pensacola, Fla., on snapper bank; 45 fathoms; July 31, 1938; collected by the *Pelican*; 208 mm in standard length; the caudal damaged at tip, about 263 mm in total length.

Paratypes.—Pensacola, Fla. (21339, 30838); off Cape Fear, N. C. (collected by the Albatross III); Charleston, S. C. (20981); Rio de Janeiro (83181), Brazil; a specimen obtained by the trawler *Santa Maria* on the coast of Brazil, locality not stated (87741); New York market (22868–9). Total paratypes 15, 138–507 mm.

Remarks.—This porgy, which is not uncommon on the American coast and sometimes enters the commercial catch, has been identified hitherto with the European *Pagrus pagrus*. However, the corresponding populations from the two sides of the Atlantic represent distinct species, as determined by comparing the 16 American specimens which form the basis of the preceding account with three specimens 155–391 mm from the Azores.

The American species normally has 16 pectoral rays, the three Azores specimens 15. As the total number of available specimens are relatively few, the rays in both pectorals were counted for each fish. As stated above, of 32 counts of American fish 29 were 16 and 3 were 15. The six counts of Azores fish were all 15. Hence, out of 32 American counts three intergrade with the European species. This gives an index of divergence of 95 (Ginsburg, 1938), which is of species magnitude, judged by the small samples examined.

The American species has a slenderer caudal peduncle, as shown in Table 2, with no intergradation between the specimens measured.

Another possible difference refers to color. As described above, the American species has very small spots which disappear after long immersion in preservative, while no such spots are mentioned in descriptions of *Pagrus pagrus* by European authors which were consulted.

TABLE 2.—FREQUENCY DISTRIBUTION OF THE DEPTH OF THE CAUDAL PEDUNCLE IN PAGRUS PAGRUS AND P. SEDECIM, EXPRESSED AS A PERCENTAGE OF THE STANDARD LENGTH

Species	9.0	9.5	10.0	10.5	11.0	11.5
sedecim...........	1	6	6	2		
pagrus...........					2	1

Archosargus oviceps, n. sp.

GULF SHEEPSHEAD

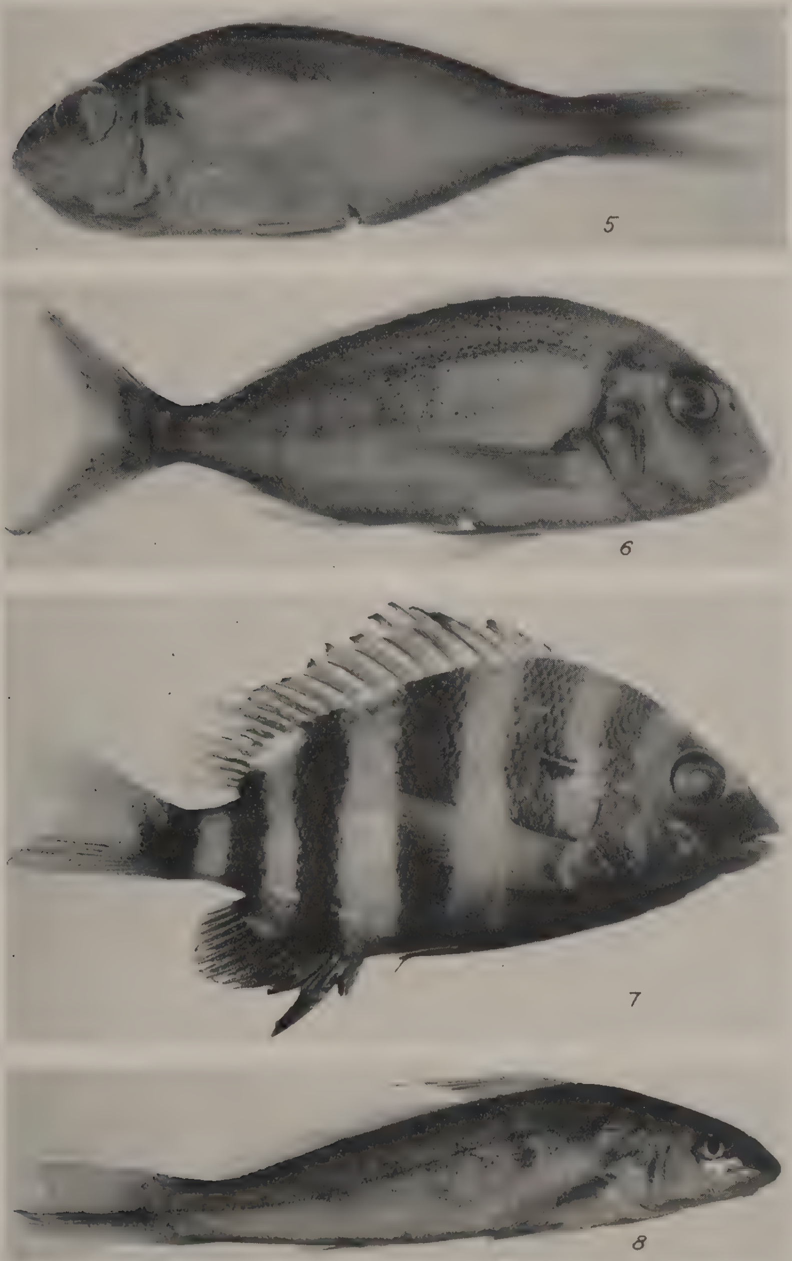
D XI–XII (XIII) 11–12. A III 9–10. P 15–17. Sc 45–49.

Dorsal spines modally 12 (in 20), very often 11 (in 11), infrequently 13 (in 1); dorsal rays modally 11 (in 20), very often 12 (in 12); number of spines and rays highly correlated, variants having 12 spines usually also having 11 rays and vice versa (D XII 11 in 17; D XI 12 in 10; D XII 12 in 2; D XI 11 in 1; D XIII 11 in 1). Anal spines constant; anal rays modally 10 (in 8), very often 9 (in 4). Pectoral rays modally 16 (in 16), often 17 (in 6), sometimes 15 (in 2). Glli rakers short, stubby, 6 or 7 on upper limb of first gill arch and 8 or 9 on lower, or 14–16 altogether. Notably deep, depth about one-half the standard length; anterior profile curving steeply to dorsal origin. Mouth rather small, terminal, only slightly inclined, nearly horizontal; the two jaws subequal in front. Maxillary ending under anterior margin of eye. Preorbital notably wide. Outer teeth broad incisors, confined to anterior part of jaws, six in upper jaw, eight in lower, with three notches or four cusps in young, becoming worn with growth; inner molars well developed, those behind incisors smaller and in three irregular rows, those on side notably broader and in two rows in lower jaw, three rows in upper jaw; no teeth on vomer, palatines or tongue. Opercle of nearly uniform thickness, forming a rather broad, rounded projection posteriorly, without spines (the projection nearly spinelike in small fish). Margin of preopercle slightly serrate to smooth. Anterior boundary of scalation a nearly horizontal, curved line with its apex on a vertical about through anterior margin of eye or a little behind; interorbital only partly scaled; cheek with a moderately broad, bandlike scaled area, tapering upward, anterior boundary of scales on cheek a line a little behind eye to end of maxillary; opercle and interopercle scaled; preopercle, preorbital, snout and lower jaw scaleless. Lateral line rising moderately upward, running at a considerable distance from, and nearly parallel to dorsal contour, slightly nearer it posteriorly than anteriorly, making a moderate curve at caudal peduncle. Anterior four dorsal spines rapidly and somewhat unevenly graduated, the first a little more than half as long as second, the fourth only slightly shorter than fifth and longest, thence gradually decreasing in length to last or penultimate; first ray moderately longer than last spine, emargination between spinous and soft parts of dorsal very moderate. Second anal spine longer and stouter than third. Ventral placed behind pectoral, about reaching anus, the outer ray usually a little prolonged. Pectoral about reaching third body band, that is, a vertical through approximately third anal spine. Caudal moderately emarginate.

Measurements of two specimens 103–115 mm and 2 large ones 235–247 mm, expressed as a percentage of standard length, measurements of smaller specimens in parenthesis. Caudal, slightly frayed (31–31.5) 30–30.5; ventral (29–29.5) 27–28; pectoral (35.5–36) 41–41.5, a little damaged in larger specimens; depth (48–53) 50.5–52.5; head (33.5 in both) 33–34; maxillary (12–13) 13 in both; snout (13.5–14.5) 15.5–17; eye (9–9.5) 7–7.5; interorbital (11–12) 11.5–12.5.

Sharply cross banded; a band on nape somewhat oblique, tapering downward, not extending on head, usually not as intensely pigmented as posterior bands; body with 5 broad black sharply marked bands extending nearly all the way down; first and fourth bands under beginning and end of dorsal, respectively, only two other bands under dorsal base; last band at caudal base; a transverse blotch on caudal, at its base, often esent, somewhat coalescent with last band; an xillary spot on lateral line, placed on and more tensely pigmented than first body band, somemes imperceptible; ground color grayish with a silvery or golden tinge; dorsal, anal and ventral almost uniformly dark to nearly black; caudal dusky; pectoral yellowish.

Only two small specimens, 14–35 mm, have an



Figs. 5–8. 5, *Pristipomoides andersoni*, n. sp., holotype; 6, *Pagrus sedecim*, n. sp., holotype; 7, *Archosargus oviceps*, n. sp., holotype; 8, *Menticirrhus focaliger*, n. sp., holotype.

asymmetrical color pattern, five body bands on one side, six on the other. All other 76 specimens have 5 body bands on both sides, except that in four of the smallest specimens the last one or two bands are more or less faint or irregular. As in *probatocephalus* (see below), specimens with an asymmetric color pattern possibly die before attaining any considerable size.

Holotype.—U. S. N. M. no. 144151. Barataria Bay, La.; Isaac Ginsburg; November 24, 1931; in shrimp trawl; 103 mm.

Paratypes.—Mobile, Ala. (19525). New Orleans, La.; Couch (727). Galveston, Tex.; D. S. Jordan (31041). Port Lavaca, Tex.; Graham (726). Brazos Santiago, Tex.; Emory (728) and J. Wurdemann (730). Tampico, Mexico; Snyder (62282). The following were collected on the coast of Texas by J. C. Pearson, in 1926: Gulf of Mexico (144158). Harbor Island (144152–5 incl., C. N. H. M.). Shamrock Cove (144156). Ingleside (144157). Corpus Christi (144160). Corpus Christi Pass (144159). Total paratypes 77 specimens, 11–355 mm.

Remarks.—This species differs from *A. probatocephalus* in normally having five bands on the body, not counting the band on the nape, instead of six. The band on the nape, the one at the caudal base, and one each under the beginning and end of the dorsal, occupy the same positions in *oviceps* and *probatocephalus*; but between the latter two bands *oviceps* has only two others, while *probatocephalus* has three. Other structural differences between the two species are not pronounced; *probatocephalus* apparently averaging a slightly higher dorsal spine count and slightly lower pectoral and gill raker counts.

Of the South American *A. aries* only one specimen was examined, from Venezuela. It is apparently nearer to *probatocephalus* than to *oviceps*. *A. aries* has six body bands like *probatocephalus*, but the bands are appreciably narrower. In meristic counts the single Venezuelan specimen agrees with *probatocephalus*, and the differences between *aries* and that species remains to be determined by a study of adequate samples.

Archosargus probatocephalus (Walbaum)

As the only substantial character determined that distinguishes *oviceps* from *probatocephalus* refers to the number of bands, a study of the variability and development of this character in *probatocephalus* was made for comparative purposes. Variation in the number of bands is shown in Table 3. All specimens are divided into thre groups: (1) With six body bands, not includin the incomplete band on the nape, (2) with fiv body bands, and (3) asymmetrical, five band on one side, six on the other, the column headin being "6/5". Of the 269 specimens examine (six from western Florida, the rest from th Atlantic), 24 or slightly less than 9 percent ar asymmetrical, and 14 or a little over 5 percen have five bands. The total of both variant categories is slightly over 14 percent.

Table 3.—Frequency Distribution of Number of Body Bands in Archosargus probatocephalus

Locality	Length of specimens in mm	Distribution		
		6	6/5	5
Beesleys Point, N. J.	25–74	24		1
Beaufort, N. C.	10–68	182	24	13
Miscellaneous, Chesapeake Bay to Key West	71–361	19		-
Homosassa and Tampa Bay, Fla.	92-252	6		

Table 4.—Frequency Distribution of Number of Body Bands in Archosargus probatocephalus as Related to Size of Specimens

Number of body bands \ Length of specimens in mm.	10–25	26–41	42–58	59–74	92–361
6	68	80	53	6	24
6/5	5	16	3	—	—
5	5	5	3	1	—

Table 3 also shows that all variants except on are from Beaufort. The latter composite sampl comprises young fish, 10–68 mm, which forme the basis of the account of development of th species by Hildebrand and Cable (1938), and study was made of the development of the band in this species.

At 10 mm the bands are not sharply outline but the chromatophores are already crowde in definite transverse areas which are separate by narrower intervals that are almost devoid c chromatophores. By this arrangement the numbe of bands in fish as small as 10 mm is determinabl On growing another 2–5 mm, the bands becom sharply outlined.

Table 4 shows the grouping of the varian with respect to size. They are present in th smaller size groups and evidently disappear wit growth. The largest 5-banded fish is 74 mm, th largest asymmetrical specimen 53 mm. Spec

ens 92 mm or longer, 24 in all, have a symmetri-
l 6-banded pattern. An obvious and plausible
planation is that in *probatocephalus* an asym-
etric and a 5-banded color pattern is linked
ith a lethal factor which results in the failure
such variants to reach some size, much less
reach adulthood. It can hardly be explained
at the asymmetric or 5-banded pattern changes
ith growth to a 6-banded pattern, as the posi-
on of the bands is constant and there would
ve to be a radical rearrangement of the chro-
atophores to produce this change, which is
rdly probable. The isolating mechanism that
eeps *probatocephalus* and *oviceps* as separate
ecies, therefore, seemingly includes two factors,
e geographic, and another which may be termed
ysiologic, using the term in a broad sense. While
e evidence is not based on a sufficient number
specimens to be altogether conclusive, it is
irly presumptive of this conclusion.

Family SCIAENIDAE

Menticirrhus focaliger, n. sp.

GULF MINKFISH

D X; I 24–25. A I (7) 8. P 19–21. Sc 75–86.
Dorsal rays 24 (in 6) or 25 (in 5). Anal rays
ormally 8 (in 26), infrequently 7 (in 1). Dorsal
nd anal spines constant (in 11). Well elongate;
ather fusiform, but tapering posteriorly more
an anteriorly and upper profile more curved
an lower. Snout long, bluntly rounded at tip,
omewhat conical, projecting beyond upper lip.
Iouth small, nearly horizontal, notably inferior,
laced well behind tip of snout. Maxillary ending
nder middle of eye or posterior margin of pupil.
nterorbital subequal to eye diameter. A single,
hort, rather stout, truncate barbel at chin.
ower jaw with five pores, one on midline of chin,
t base of barbel, two on both sides. Anterior
argin of snout with four lobes well developed.
eeth in jaws in rather broad bands; small,
xcept outer teeth in upper jaw rather well
nlarged, the others subequal; vomer and pala-
ines toothless. Gill rakers short, rather stout,
tumpy, comparatively few, the anterior 2 or 3
ill rakers on lower limb better marked in the
maller specimens, reduced to low tubercles or
o a few spinules at the surface or hardly per-
eptible in the larger specimens (hence the tu-
ercles were not counted, and the gill raker count
iffers with size), 5 + 7–10 in the smaller speci-
ens (four specimens 53–81 mm), 5 + 6–8 in
he larger (six specimens 90–132 mm). Hard part
of opercle ending in two widely separated, moderately pungent or flexible points, without well marked spines. Preopercle moderately serrulose or crenate, the points moderately pungent or flexible. Scaled all over; except a moderate area at anterior end of snout naked; scales on chest subequal, the middle scales not notably smaller than those at periphery; scales on lateral aspect of snout and anterior part of cheek cycloid, others ctenoid; proximal part of caudal scaled, distal part scaleless, except the modified lateral line scales extending to its distal margin; ventral and pectoral scaled for a short distance at base; a single row of scales on second dorsal base; spinous dorsal and anal scaleless. Spinous and soft dorsal well separated, forming two fins; the spines flexible; second to fourth spines prolonged, the third longest; extent of prolongation varying greatly with the individual and increasing with growth, tip of longest spine reaching base of third to eighth dorsal ray in specimens 53–103 mm (25 fish), to base of ninth ray in specimens 115–132 mm (2 fish). The single anal spine flexible in the larger specimens, moderately pungent in small ones. Ventral placed at some distance behind pectoral base, falling considerably short of anus. End of pectoral falling a little short of a vertical through end of ventral in the smaller specimens, extending to or a little behind that vertical in the larger fish. Caudal asymmetrical, lower part rounded, longer than upper part, the latter emarginate.

Measurements of six specimens 90–132 mm, including the holotype expressed as a percentage of standard length: Caudal (lower part) 25–27.5, ventral 18–20, pectoral 20–22, depth 24–25, head 30–31.5, maxillary 10.5–11, snout 10–11, eye 6–7.5, interorbital 6.5–7.5.

Ground color light yellowish or grayish; with dusky or black rather wide bands; four oblique bands under dorsal fin running downward and forward, the first band under end of spinous dorsal continued upward on posterior part of fin, the fourth at some distance before end of soft dorsal, the bands decreasing in length and increasing in obliquity from first to fourth; two oblique bands on nape running in opposite direction to preceding series, downward and backward; the first band of the posterior series and the second band of the anterior series forming a broad V on side; caudal with a dusky longitudinal band along middle of its lower half, often rather faintly continued forward on posterior part of

TABLE 5.—FREQUENCY DISTRIBUTION OF THE NUMBER OF SCALES AND PECTORAL RAYS OF MENTICIRRHUS FOCALIGER AS COMPARED WITH M. SAXATILIS.

Species	Scales																														Pectoral rays			
	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	18	19	20	21
focaliger	1	1	2	2	4	4	4	1	2	1	2	2																			2	3	17	4
saxatilis:																																		
North Carolina															2		3	1	1		2	1	1	1								1	2	8
Woods Hole																			1		2	1		2	1	1	1	2		1			10	6

body. The oblique bands described above are sometimes sharply black and sometimes hardly perceptible. Usually they are of a diffusely dusky pigment. In general the bands are better marked in the smaller specimens. In life they are more sharply outlined than in preserved specimens.

Holotype.—U. S. N. M. no. 144161. St. Joseph Bay, Fla., near its entrance; Isaac Ginsburg; June 21, 1932; 132 mm.

Paratypes.—Five specimens 90–114 mm, obtained with holotype (U. S. N. M. no. 144163). Cape San Blas, Fla.; Isaac Ginsburg; June 20, 1932; 21 specimens 53–103 mm (U.S.N.M. no. 144162; C.N.H.M.).

Remarks.—I obtained the above 27 specimens on two successive days at two localities not far apart by means of a 30-foot seine on sandy beaches. Several drags of the net were made at each place and every drag brought in one or more specimens of *focaliger*. Very likely I could have obtained more specimens by further seining; but at the time I thought that they represented the common *saxatilis*. At Cape San Blas, 38 specimens of *M. americanus* and 5 of *M. littoralis* were obtained in the same drags as the 21 *focaliger*. Evidently the three congeneric species live and mingle side by side.

This species is close to *M. saxatilis* from the Atlantic, nearly agreeing with it in normally having 8 anal rays, in the extent of prolongation of the dorsal spines, in the color pattern and the size of the scales on the chest. It differs chiefly in having a lower scale count as shown in Table 5. While counts of more specimens might show some overlap in the distributions of the two species, the extent of divergence is evidently of species magnitude or very close to it. The populations of *saxatilis* from Woods Hole and North Carolina also differ in the scale count, possibly to an extent to be treated as distinct subspecies; but such is not unusual for north and south populations of the same species. The pectoral count of *focaliger* is nearer to the Woods Hole population of *saxatilis* than to the North Carolina population.

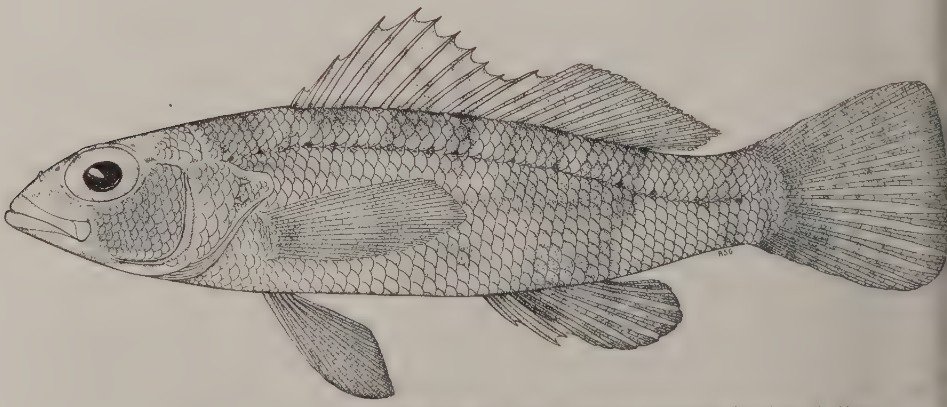


FIG. 9.—*Serraniculus pumilio*, n. gen. and sp., drawn from a paratype by Ann S. Green.

TES ON THE GEOGRAPHIC DISTRIBUTION OF THE FISH FAUNA OF THE EAST OAST OF THE UNITED STATES WITH PARTICULAR REFERENCE TO THREE F THE SPECIES ESTABLISHED ABOVE

The relationship of the temperate-water, marine n fauna of the Atlantic and Gulf coasts of the ited States constitutes an interesting problem zoogeography. The peninsula of Florida forms effective natural barrier to the spread, and ults in the isolation, of fish populations. The lf fish fauna from the Rio Grande (very little now known of the fishes on the Mexican coast), , roughly to Cape Romano, Fla., is on the ole very similar to the temperate-water fish na of the Atlantic coast of the United States. ost species of both coasts are nearly identical ith some qualifications as discussed below). e southern limit of the temperate Atlantic na is somewhere between Cape Canaveral and scayne Bay, Fla. The fauna of the extreme d of southern Florida, on the other hand, from scayne Bay to Tortugas, is in its larger aspects pical and very similar to or nearly identical th the West Indian fish fauna and that of ntral and the tropical part of South America. e very similar temperate fish faunas of the lantic and Gulf coasts are thus isolated by the ysical barrier of the peninsula of Florida and the ecological barrier of the tropical waters the Florida keys.

The division between the temperate water and pical fish faunas is not sharp. Many species have a discontinuous geographic range. They cur on the Atlantic and Gulf coasts of the nited States; but their geographic distribution interrupted by their absence at the Florida ys. On the other hand, from the viewpoint of ogeography, a second category contains many ecies, in the families Carangidae and Lutiani- e for instance, which have a continuous range, om the Atlantic coast, around the Florida ys, to the Gulf coast and also to the West dies and Central America. The ichthyofauna the Florida keys is not well enough known to ake a numerical comparison of the species in ese two categories. Whatever the relative num- er of species in the two categories, those species hich by their preponderance in numbers give aracter to the fauna, have a discontinuous dis- ibution. For instance, the temperate-water annel bass, croaker, spot, sea trouts, and men- aden, species that dominate the faunal scene their abundance, have a discontinuous dis- ibution. Also, most species having a continuous ographic range, typically belong rather to the tropical fauna. Their center of abundance is at the West Indies, the Florida keys and the coast of Central America, and occur only sparingly farther north on the Atlantic and Gulf coasts of the United States. Fewer species with a continuous geographic range, such as the sheepshead and the pigfish, typically belong to the temperate water fauna and occur in much reduced numbers at the Florida keys.

As a general rule species are not uniform morphologically throughout their geographic ranges; they differ more or less with the local population. Two species having a continuous distribution, which I have studied in detail, namely, *Bathygobius soporator* (Cuvier and Valenciennes), sensu lato (Ginsburg, 1947), and *Bathystoma aurolineatum* (C. and V.), sensu lato (1948) show that the populations of the Florida keys are somewhat intermediate, between the comparable West Indies populations and those farther north on the coast of the United States.

Comparisons made of the corresponding pairs of populations—one from the Atlantic, the other from the Gulf—of species having a discontinuous geographic range show that they too diverge more or less morphologically. The extent of divergence of comparable pairs is of different degrees and their magnitudes form a graded series, from very slight to very pronounced, with all gradations in between. (A difference in degrees of divergence among species of the same genus even, is mentioned above under the account of *Centropristes melanus*.) An example near the low end of the series is furnished by the Atlantic and Gulf populations of *Cynoscion nebulosus* as discussed by me in another paper (1938), which also gives a number of other, graded divergences at or below the subspecies level. The divergences of two corresponding pairs, namely, *Brevoortia tyrannus* from the Atlantic as compared with *B. patronus* from the Gulf, and *B. smithi* as compared with *B. gunteri*, recently published by Hildebrand (1948), are evidently of higher degrees, near the borderline between species and subspecies. The divergence of two pairs compared above, namely, *Centropristes striatus* with *C. melanus* and *Menticirrhus saxatilis* with *M. focaliger*, is approximately the same as the above named two pairs compared by Hildebrand. Finally, as an example near the other extreme, that of very pronounced divergence, the two species of *Stenotomus* may be cited. *S. chrysops* (Linnaeus) is common on the Atlantic coast of the United States and is replaced on the Gulf coast by *S. caprinus* Bean which is not known to occur in the Atlantic. This is an example of two closely related allopatric species which replace each other geographically but which are so highly divergent that they are often placed by authors in separate genera.[1]

In sum, subject to the qualifications and exceptions discussed, by and large, the fish fauna of the Florida keys is tropical and West Indian, while that of the Gulf is very similar to the temperate water Atlantic fauna. The two very similar temperate water faunas are isolated by the peninsular barrier. This barrier is such a striking feature in the geographic distribution of the icthyofauna that it could not have escaped the notice of students of fishes. But it is only lately that a beginning was made towards a detailed study and evaluation of the results of its influence on the ramification of fish populations. In any further studies, it would be interesting to note whether the change in the general character of the fauna at the lower end of the peninsula of Florida is fairly abrupt or gradual, and if abrupt at what area the change occurs.

The geographic distribution of three species described here is not in line with the general relationship of the temperate faunas on both sides of the now existing peninsular barrier as discussed above. The sheepshead, *Archosargus probatocephalus*, is one of those fewer among the typically temperate-water species that have a continuous geographic distribution, occurring as it does, in reduced numbers, in the Florida keys. A comparison of the specimens examined from Tampa Bay and Homosassa with those from the Atlantic coast makes it evident that any divergence that might exist between the Atlantic and west Florida populations will prove to be of very minor degree, decidedly below the subspecies level. This relationship is similar to that of the populations of many other species on the opposite sides of the peninsular barrier. However, in the case of the sheepshead, something different is also indicated. The population on the west coast of Florida differs materially from the comparable population on the coast of Alabama, Louisiana, Texas, and Mexico, the difference being such that they may be treated as distinct species; that is, on the Gulf coast westward of Florida *probatocephalus* is replaced by a distinct species, *oviceps*. A similar, though not parallel, difference in distribution is indicated further by two other species here described, *M. focaliger* and *C. melanus*.

The two species of *Menticirrhus* compared above, *focaliger* and *saxatilis*, are examples of tw corresponding populations that replace each othe on the two sides of the peninsular barrier an that have attained a divergence of species magnitude. This also is not unusual. Similar instance have been cited above. However, *focaliger* apparently does not occur on the Gulf coast westward of Florida. Of the thousands of specimens closely examined or observed on the coast c Louisiana and Texas, not a single *focaliger* wa found; they all comprised two species, *americanu* and *littoralis*, which also occur on the west Florid and Atlantic coasts. *M. focaliger* is also lackin among the many specimens of *Menticirrhu* which John C. Pearson preserved during hi study of the sciaenids of the Texas coast, and i was not found in the National Museum. It seem safe to conclude, therefore, that it does nc occur in the Gulf west of Florida. Apparently thi also holds for *Centropristes melanus*. The latte species has been masquerading heretofore unde the name *C. striatus*. There are no indisputabl records of its having been taken westward c Florida. I have not encountered it in my co lecting trips from Alabama to Texas; and n specimens from the coast of those States a present in the large collection of *Centropriste* in the National Museum. Weed (1937) gives a extensive annotated bibliography of *Centr pristes*. None of the references cited contain a undoubted record of the black seabass west

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[1] As the above statements regarding *Stenotomus* are at variance with published accounts, it should be here said that they are based on original and as yet unpublished data and observations. I did this work in preparing an account of the Gulf coast fishes. The specimens of *Stenotomus* examined from the Atlantic range from the Bay of Fundy in the north to Cape Canaveral, Fla; those of the corresponding population in the Gulf range from Pensacola, Fla., to Aransas Pass, Tex. Of the Atlantic material a few specimens from near the extremes of their geographic range were studied in detail and compared with those in the Gulf. All available specimens, more than 100 in number, were then examined for the most critical distinguishing characters. As a result of these studies I have come to the conclusion that only two species of the common scups are known, namely, *Stenotomus* (*Stenotomus*) *chrysops*, which is confined to the Atlantic, and *Stenotomus* (*Otrynter*) *caprinus*, which is confined to the Gulf. Judged by analogy, by the distribution of *Archosargus probatocephalus*, as determined during this investigation and recorded above, *S. chrysops* might occur in western Florida, but this remains to be determined.

ida. One reference, that by Collins and
th, recording *C. striatus* as being a commercial
ies in Mississippi, is most probably based not
ctual specimens but on reports of fishermen
fish dealers, and it very likely refers to some
er species designated "seabass" in the fish
le of Mississippi, rather than to *Centropristes*.
specimens that Weed designated as *striatus*
that are designated above *melanus* all came
n Florida.

till another example, again not altogether
llel, is furnished by the species of *Hippo-*
pus (Ginsburg, 1937). *H. zosterae* occurs on
coast of Florida and is replaced on the coasts
Mississippi and Texas by the closely related
morphologically somewhat overlapping *H.*
lus. This case is not altogether parallel in as
ch as *H. zosterae* is not known to occur in the
antic north of Biscayne Bay; but it indicates a
ked difference in the fish fauna between the
f coast of Florida and the coast westward of
rida.

he peculiar geographic distribution of the
r species discussed, as compared with their
e relatives, challenges a rational explanation.
the surface the existing ecological conditions
the greater part of the Florida west coast
not so strikingly different from those of most
er parts of the Gulf coast as to account for
difference in geographical distribution. Yet,
some important elements, the fish fauna of
Gulf coast of Florida differs markedly from
t of the coast of Alabama and westward and
earer to that of the Atlantic coast.

n our present state of knowledge only specu-
ve suggestions may be made. One such sug-
tion would be the existence of some past or
sent barrier, now unrecognized. On this as-
nption the thought that comes to mind first
n ecological barrier, namely, the soft or muddy
ure of the bottom in the delta region resulting
m the tremendous mass of silt carried down
the Mississippi River. But, while this may
a partial factor in isolating fish populations,
evidently does not offer a full explanation of
peculiar distribution here discussed. Most
cies are able to surmount this barrier. More-
er, the fauna on the coasts of Alabama and
ssissippi, on the east side of the Mississippi
lta, is the same as far as we know now as that
Louisiana and Texas, west of the delta. Another
umption would be the probable existence of
faunal barrier, similar to the now existing
insular barrier, physical or ecological, in some
t geologic epoch, perhaps the Pliocene, somewhere between what is now Cape San Blas, Fla., and Mobile Bay, Ala. This hypothetical barrier must have antedated the peninsular barrier as it now exists. It produced its effect in isolating fish populations when the west coast of Florida was still continuous with the Atlantic coast, at least when it was climatologically and ecologically uninterrupted and supporting the same fauna. The proof of such a hypothesis, of course, lies within the province of historical geology as well as zoogeography. My main object here is to place the zoogeographic evidence on record as it relates to fishes, for the purpose of correlation with similar evidence that might exist for other groups or that might be discovered in the future study of fishes.

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Fishes of the Family Carangidae of The Northern Gulf of Mexico and Three Related Species

By

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This paper is the result of a study of the fishes of the Gulf coast of the United States which is being continued. It deals with the family Carangidae which includes such well known food and game fishes as the pompanos, the amberjacks and the cavallos.

The species which have been recorded from, and those which have been found during this study to occur within the geographic limits of the the coast extending from the mouth of the Rio Grande in Texas to Cape Romano, Florida, are here treated. While this arbitrarily fixed geographic extent is limited, it includes the large majority of the well authenticated species of this family found in the western Atlantic, that is, excluding species, or records in current lists, that are of doubtful validity.

Three species not now known from the region under consideration are here included for comparative purposes, as follows. *Alectis crinitus* is one of a group of three genera, including *Selene* and *Vomer*, the species of which undergo extraordinary changes with growth. These changes have been determined and are hereafter described insofar as the available material permitted. The other two species, *Seriola fasciata* and *Trachinotus marginatus* are here included; because in order to understand the species of these two genera occurring in the Gulf, it was found necessary to make a detailed study of all the available western Atlantic specimens. The accounts of *Seriola* and *Trachinotus* given below virtually represent reviews of the species of those two genera found on the east coast of the United States and possibly include all the western Atlantic species.

The accounts given here are based on data determined first hand by a study of specimens of every species. The specimens examined are chiefly those in the National Museum collection and those obtained by the U. S. Fish and Wildlife research boat *Pelican*, supplemented by some specimens from other sources. Numbers given in parenthesis in listing specimens examined, refer to U. S. National Museum numbers.

Two of the results of the present study, among others, may be especially mentioned here as follows: (1) Four species of amberjacks are here definitely distinguished from the east coast of the United States, and these very likely include all the species found here. (2) Based on the samples examined, the so-called "permit" apparently does not represent a distinct species; but this name is applied to large specimens of *Trachinotus falcatus,* perhaps also to large specimens of *T. carolinus*.

As in other papers resulting from this continued study, which have been published or are now in press, the family description includes the characters common to the species and genera here treated and are not repeated under their accounts. Likewise, when a genus contains two or more species, the characters common to the species are stated under the genus and are not repeated under their accounts. Also, the definition of the family and those of the genera apply only to the species included in this paper and are not formulated on a world wide basis. As a further means of promoting brevity, and to prevent the cluttering up of the account with non-essential matter, only the important characters that distinguish the genera and species are described.

Depending on the available material, intraspecific variability of the essential characters has been determined on a moderate number of specimens and stated under the accounts of the species, except in difficult and critical cases where frequency distributions are given in tabular form.

Measurements are expressed as a percentage of the standard length, except where otherwise stated. Given lengths of specimens refer to the distance from tip of snout to tip of upper caudal lobe.

Color descriptions are based on preserved specimens.

Synonymies include only references to general works, other important references and records from the northern Gulf coast. No attempts have been made to compile complete bibliographies to the genera and species. As a consequence, the entire geographic range and the recorded maximum size to which the species attain are omitted from their accounts. (Indeed, on account of questionable identifications, records of size in some instances are doubtful.) But under the accounts of each species, the localities from which specimens were examined and their maximum sizes are stated.

According to authors, some of the species, such as *Caranx hippos, Selar crumenophthalmus*, and others, have a wide distribution in the Atlantic and Pacific. In my study of the species for this faunal work, no attempt was made to study specimens from the recorded entire geographic range of such species, and their possible population differences. My studies were confined to and the following accounts are based on specimens from the western Atlantic.

Family CARANGIDAE

Amberjacks, Cavallos, Pompanos and others

Form differing widely with the genus from slender to excessively deep and from moderately to excessively compressed. Caudal peduncle of medium width to notably slender, depressed to compressed, with a median lateral ridge present or absent; a short ridge close to and above lateral line and a similar ridge below, placed partly on peduncle and partly on caudal fin, present in some genera (present in the smaller specimens of *Caranx*, becoming more pronounced with growth; also in the largest specimens examined of *Vomer* and *Alectis;* absent in specimens examined of the other species; in some of these species perhaps developing in larger specimens than those examined). Adipose eyelid moderately to well developed. Maxillary narrow to broad; supplemental maxillary present or absent; end of maxillary falling short of a vertical through anterior margin of eye, or reaching through its posterior margin. Mouth terminal to superior, of moderate extent. Teeth small to minute, subequal, or outer teeth in jaws moderately enlarged; no canines; those in jaws in moderate bands, differing to one row; present or absent on vomer, palatines or tongue, depending on the species (all teeth disappearing with growth in *T. carolinus* and *T. falcatus*). Hard part of opercle with a small emargination above, the opercle above and below emargination widely or rather narrowly rounded, not spinous; soft part bridging emargination with a dark or black spot in several species; preopercle not serrate, smooth or slightly crenate. Gill opening large, branchiostegal membrane forming a slight fold across isthmus under eye or a little in advance. Pseudobranchiae well developed, except in *Trachinotus*. Gill rakers moderate in length and number to slender and numerous. Position of anus differing with species from near first anal spine to near ventral base. Scales small to minute; body altogether scaled or nearly so, except in *Vomer setapinnis* and *Alectis crinitus*; cheek, opercle and antedorsal area scaled or naked; interorbital and interopercle scaled in *Selar*, *Decapterus* and *Trachurus*, scaleless in other genera; rest of head naked; spinous dorsal scaleless, other fins scaled or not depending on species. Anterior part of lateral line usually somewhat sinuous, curved, differing from a high arch to very slightly curving; posterior part armed with slightly or strongly developed scutes or unarmed; an accessory lateral line beginning nearly over preopercular margin, running upward, curving a little below dorsal contour and continued backward for a distance differing with the species. Procumbent dorsal spine present, in the young slightly to well developed, generally becoming reduced with growth and also covered by thick skin and often hardly preceptible in large specimens. With two separate dorsal fins; first dorsal of moderate height or very low; with 5–8 spines, some or all greatly reduced in length, most of them rather flexible or all pungent, connected by membrane or disconnected, depending on the species; midback at base of spinous dorsal with a groove continuous or interrupted, the spines folding backward into groove (the last 2 spines in some species usually or often lying flat against the back and hidden in the groove, and unless examined with care their presence might be missed); second dorsal with one spine, more or less flexible, closely adherent to following 18–40 rays; structure of dorsal changing markedly with growth, in the young, of some species at least, the spines stouter, relatively longer and pungent, instead of flexible, the single spine of the second dorsal similar to those of the first dorsal, and the two fins more or less connected, continuous in some species; with growth the two fins becoming well separated, the one spine of the second dorsal becoming flexible and intimately merging with rest of fin; spines of first dorsal becoming relatively reduced, sometimes strikingly so, some of them becoming thin and more or less flexible, part of them (in *Vomer setapinnis*) or all (in *Alectis crinitus*) virtually disappearing with growth. Anal similar to dorsal in structure and development, in grown specimens typically consisting of two separated spines, well disconnected from soft part of fin, and one spine, flexible or pungent, intimately connected with following 15–30 rays; in young, of some species at least, the three spines well developed, stout, pungent, connected by membrane and the anal fin continuous; with growth the two anterior spines becoming disconnected and removed at some distance from rest of fin, becoming reduced in relative length, one or both disappearing in some species. Last dorsal and anal ray more or less thicker than preceding rays; becoming detached from rest of fin to form separate finlet in two genera (finlet consisting of one ray in *Decapterus*, of two rays in *Elagatis;* in *Oligoplites* most rays in form of partly attached finlets). Anterior dorsal and anal rays only a little elevated or excessively so, the degree of elevation differing with the species and changing intraspecifically with growth. A fold of skin at base of dorsal and anal, the two fellows forming a troughlike sheath for base of fin, well or moderately developed anteriorly, absent or moderately developed posteriorly; scaled; obsolescent in some species. Ventral short to long, its outer angle on a vertical differing from well in front of the lower pectoral angle to a little behind. Pectoral with 15–23 rays, hardly to notably falcate, short to notably long. Caudal well to notably forked or lunate, its length differing with the species.

Contrary to many other fishes, in many species of this family the body depth is proportionately greater in the young and decreases with growth.

Dorsal and anal finlets evidently appeared independently in different lines of descent within the family. Of the two Gulf genera having an entirely detached finlet, *Elagatis* is evidently nearly related to *Seriola*, and *Decapterus* is near *Selar;* but are rather remote from each other. *Oligoplites* which has a number of only partly detached finlets is still wider apart from either *Elagatis* or *Decapterus*.

This family is notably heterogeneous, including genera which differ widely in structure and appearance. Some attempts have been made by authors to divide the Carangidae in a number of subfamilies; but such attempts did not prove satisfactory for two reasons: (1) Some of the characters hitherto used for this purpose are unsatisfactory. (2) The presence of transitional genera prevents the drawing of well marked lines between the groups which have been proposed as subfamilies.

Key to the genera and species

1a. Maxillary protractile. Scales normally rounded, those in lateral line variously modified. Fin rays having the prevalent structure and attachment to one another, except one dorsal and anal finlet present in *Elegatis* and *Trachurus*.

2a. Lateral line without spinous scutes, the posterior scales sometimes with a slight or moderate longitudinal ridge; body elongate or deep, but anterior contour of fish as usual, tapering forward to the rounded or blunt snout; and gill rakers on lower limb not more than 20; the three characters going together. Pectoral rather short, hardly or slightly falcate. Dorsal and anal lobes very moderately raised to very long.

3a. Snout having the usual piscine shape, tapering forward, subconical. Maxillary broad, its width subequal to eye in the larger specimens, with a well developed supplemental maxillary. Spindle shaped, elongate to oblong, depth 24–42. First dorsal with 6–8 spines connected by membrane, except last one or two. Second dorsal having 7–19 more rays than anal.

4a. Without detached dorsal and anal finlets. First dorsal with 7–8 spines, 6 in very large specimens .... *Seriola* (p. 53)

5a. Total number of gill rakers on both limbs of outer gill arch, including a tubercle at one or both ends of the arch, 25–28, or 7–9+18–20; the number hardly changing with growth (growth change determined only for *falcata*). Scales 122–137. Dorsal rays 28–32.

6a. In small specimens: nuchal band oblique, running from eye to beginning of first dorsal; body bands usually 5, sometimes 6, moderately split transversely by a lighter area; all bands disappearing with growth; dorsal spines 7, except 8 in specimens 14–15 mm. In the larger specimens: preanal 59.5–62.0; dorsal lobe 21.5–27.5; anal lobe 18–20; depth 31.5–40.0 .... *Seriola falcata* (p. 58)

6b. In small specimens (large specimens not examined): nuchal band moderately oblique, not reaching beginning of dorsal; body bands 7, often widely split transversely by a lighter area; dorsal spines 8 ....*Seriola fasciata* (p. 61)

5b. Total number of gill rakers and tubercles on first arch usually 21–24, sometimes 25, or 5–7+15–19, some of the gill rakers at both ends of arch becoming so reduced with growth as to be virtually indistinguishable in most of the larger specimens, the number of well defined gill rakers in such specimens 2–4+11–14 (while gill raker count intergrades somewhat in the smaller specimens, the larger fish are separable discretely by this character). Scales 141–187.

7a. In the larger specimens: preanal 60–63; dorsal lobe 14–16; anal lobe 12.5–13.5; depth 32–35. Dorsal spines 7. Dorsal rays 30–35. Scales 141–163 .... *Seriola dumerili* (p. 63)

7b. In comparable specimens: preanal 67.0–69.5; dorsal lobe 14.0–16.5; anal lobe 10.5–13.0; depth 25.5–30.0. Dorsal spines usually 8, sometimes 7. Dorsal rays 33–40. Scales 160–187 .... *Seriola zonata* (p. 64)

4b. A detached finlet behind dorsal and anal. First dorsal with 6 spines .... *Elagatis bipinnulatus* (p. 67)

3b. Snout having a characteristic appearance, notably foreshortened, broad, blunt. Maxillary rather narrow, subequal to pupil; without a definite supplemental maxillary. Oblong to notably deep, depth 32–74. First dorsal with 6 spines (sometimes 5 in *Trachinotus carolinus*), becoming detached with growth; second dorsal having 1–4 rays more than anal .... *Trachinotus* (p. 69)

8a. Dorsal rays 18–21. Anal rays 16–18.

9a. Small specimens, up to 125 mm. in standard length, very deep bodied, depth 54–72, becoming oblong with growth (see table 12); dorsal and anal lobe in the larger specimens moderately long, that of dorsal about reaching caudal base, 36–49. Body without cross bars .... *Trachinotus falcatus* (p. 72)

9b. Body oblong, depth not more than 50 in comparable small specimens, increasing moderately in depth with growth; dorsal and anal lobe in large specimens excessively prolonged, that of dorsal reaching considerably beyond caudal base, 45–82. Body with comparatively long cross bands, except in small specimens .... *Trachinotus glaucus* (p. 76)

9c. Body oblong, depth 46–53 in 7 specimens 108–225 mm. (depth somewhat increasing with growth in the specimens examined); dorsal and anal lobes comparatively moderate, not reaching a vertical through caudal base in largest specimens examined. Body with short cross bands or transversely elongate spots .... *Trachinotus marginatus* (p. 79)

8b. Dorsal rays 23–27. Anal rays 20–23. Body usually oblong except at a certain size range (see table 15); dorsal and anal lobe moderately elevated. Without cross bands .... *Trachinotus carolinus* (p. 79)

2b. Posterior straight part of lateral line with well developed, spinous scutes, when scutes very moderate or obsolescent anterior contour of fish notably elevated, almost vertical or moderately oblique (in *Vomer* and *Selene*), or gill rakers 31–35 on lower limb (in *Chloroscombrus*).

10a. First dorsal differing in size, but having the prevalent shape, the spines graduated both ways, the anterior spines increasing in length backward, the posterior ones decreasing, connected by membrane, except last one or two spines partly or wholly disconnected; when last 4 dorsal spines short and disconnected (in large specimens of *Caranx hippos*), scutes well developed and body comparatively slender, depth 29. The two separated anal spines hinged and persistent with growth, except virtually absent in one specimen examined of *Uraspis heidi*. Fins not strikingly changing with growth.

11a. Interorbital and interopercle partly or wholly scaled. Pectoral reaching a vertical through beginning of soft anal or falling short. Anterior curve in lateral line low or moderately rising. Caudal shorter than head. Depth 19–30.

12a. Scales in anterior part of lateral line rounded, not larger than adjacent normal scales, not transversely expanded. Shoulder girdle with 2 thick papillae.

13a. No finlet behind dorsal and anal. Lower papilla on shoulder girdle larger than upper. Pectoral reaching to over beginning of soft anal in large fish. Depth 25–29 .... *Selar crumenophthalmus* (p. 83)

13b. A finlet behind dorsal and anal present. The two papillae on shoulder girdle subequal. Pectoral falling short of a vertical through beginning of soft anal. Depth 19–23 .... *Decapterus punctatus* (p. 85)

12b. Scales in anterior part of lateral line transversely expanded, similar in shape to posterior scutes, except not keeled nor spinous. Shoulder girdle without papillae. Pectoral reaching to over beginning of soft anal in large fish. Depth 25–30 .... *Trachurus lathami* (p. 87)

11b. Interorbital and interopercle scaleless. Pectoral reaching beyond a vertical through beginning of soft anal. Anterior curve in lateral line well developed, comparatively high. Caudal subequal to or longer than head, sometimes slightly shorter. Depth 29–54.

14a. Lateral line with well developed scutes. Ventral contour not notably more curved than dorsal profile. Gill rakers on lower limb 14–28.

15a. Vomerine teeth present. Outer teeth in jaws moderately enlarged. Two short keels on caudal peduncle (not evident in small specimens). Depth 29–36 in the larger specimens. Teeth in upper jaw in more than one row. Spinous points of scutes directed backward. Widest part of maxillary wider than pupil. Cheek largely scaled. The two separated anal spines present. Dorsal spines normally

8. Ventral reaching approximately half the distance from its base to anal origin. Mouth cavity without white areas .... *Caranx* (p. 90)

16a. Anal rays 15–17. Dorsal rays 19–22. Gill rakers on lower limb (excluding rudiments) 14–16. Maxillary ending under posterior margin of eye. Dorsal and anal lobe high. Scutes 30–42. Curve in lateral line long. Body rather deep.

17a. Chest scaled .... *Caranx latus* (p. 92)

17b. Chest scaleless .... *Caranx hippos* (p. 93)

16b. Anal rays 19 24. Dorsal rays 23–27. Gill rakers 17–28. Maxillary ending under anterior margin or middle of eye. Dorsal and anal lobe moderate or moderately high.

18a. Scutes 20–31. Gill rakers 17–21. Dorsal rays 25–27. Anal rays 22–24. Chord subtending curve in 1.1 moderately shorter than straight part. Body rather deep .... *Caranx bartholomaei* (p. 95)

18b. Scutes 45-54. Gill rakers 25–28. Dorsal rays 23–24. Anal rays 19–21. Chord subtending curve in 1.1. about one and two-thirds times in straight part. Body rather slender .... *Caranx crysos* (p. 96)

15b. Vomerine teeth absent. Outer teeth not enlarged. Caudal peduncle without keels. Depth 40–47 in the larger specimens.

19a. Spinous points of scutes directed backward. Upper jaw with one row of teeth. Curve in 1.1. short. Widest part of maxillary less than pupil diameter. Chest scaled. Cheek largely naked. Ventral reaching less than half the distance from its base to origin of soft anal. The two disconnected anal spines present. Dorsal spines usually 7. No white color within mouth cavity .... *Hemicaranx amblyrhynchus* (p. 98)

19b. Spinous points of most scutes directed forward. Upper jaw with 2 rows of teeth. Curve in 1.1. long. Widest part of maxillary a little wider than pupil. Chest scaleless. Cheek scaled in large part. Ventral reaching a little beyond origin of soft anal. The two disconnected anal spines virtually absent. Dorsal spines 8. Mouth cavity with large white areas .... *Uraspis heidi* (p. 99)

14b. Lateral line with a few weak or rudimentary scutes. Arch of ventral contour deeper than that of dorsal. Gill rakers 31–35. Body notably compressed .... *Chloroscombrus chrysurus* (p. 101)

10b. First dorsal reduced; the last four spines at least, short, disconnected, subequal, the fin partly or wholly disappearing in the larger specimens of two species. The two separated anal spines short in young, disappearing with growth. Fins strikingly changing with growth, depending on the species, except pectoral and caudal undergoing about a normal growth change. Scutes moderate or virtually undeveloped. Depth 48–63 in the larger specimens. Opercle scaleless.

20a. Cheek partly scaled. Scutes moderately developed with moderate spinous points. Anus about midway between ventral base and normal position of first anal spine. Ventral moderately long in large specimens. D 18–19. A 15 16. Gill rakers on lower limbs 14–16. The two separated anal spines hinged. Dorsal spines not filamentous in the young, short and pungent, disappearing with growth. Ventral notably prolonged in young, nearly equalling standard length. Anterior dorsal and anal rays excessively prolonged in the young and in medium sized specimens .... *Alectis crinitus* (p. 104)

20b. Head altogether naked. Scutes very moderately developed, without spinous points, or rudimentary. Anus placed near ventral base. Ventral very short in grown specimens. D 20–23. A 17–20. Gill rakers 23–29. Separated anal spines fixed.

21a. Anterior contour nearly vertical. Anterior dorsal and anal lobe slightly or hardly elevated. Scutes few and moderate, moderately keeled and not spinous. Upper part of body largely scaleless. Anterior 4 dorsal spines virtually disappearing in large specimens; filamentous in young, the second and longest not reaching caudal base. Ventral in young moderate, not reaching origin of soft anal .... *Vomer setapinnis* (p. 109)

21b. Anterior contour oblique. Dorsal and anal lobe notably prolonged, the length increasing with growth. Scutes obsolescent. Body, except antedorsal area, altogether scaled. All 8 dorsal spines persisting in largest specimens examined: only second and third dorsal spines filamentous in young, very long, about 3 times the standard length. Ventral in young much prolonged, about equalling standard length .... *Selene vomer* (p. 112)

1b. Maxillary not protractile. Scales acicular, narrow and long. Most dorsal and anal rays characteristically modified, in form of finlets partly attached .... *Oligoplites saurus* (p. 115)

SERIOLA Cuvier

Seriola Cuvier, Regne Animal, t. 4, p. 315, 1817 (genotype *Caranx dumerili* Risso by monotypy)

Spindle shaped, depth moderate to slender. Caudal peduncle rather deep (for a carangid) to slender, compressed to depressed, with a median lengthwise keel very slightly or well developed (in small specimens the peduncle compressed, without a keel); with a somewhat crescentic pit on its dorsal and ventral aspect, near caudal base. Snout moderately long, obtuse. Adipose eyelid moderately developed posteriorly, slightly so anteriorly. Maxillary ending under anterior margin of pupil or middle of eye, notably broadening posteriorly; supplemental maxillary well developed. Mouth of medium extent, terminal, lower jaw slightly or hardly projecting. Teeth subequal, in moderately broad bands in jaws and on palatines; those on vomer in an anchor-shaped patch, backward prolongation on shaft moderate; band on tongue of medium width. Anus near normal position of first anal spine. Scales small; antedorsal area scaled to a vertical between eye and preopercular margin; cheek and upper part of opercle scaled, greater part of opercle and rest of head scaleless; caudal scaled, other fins scaleless. Anterior curve of lateral line long and low, merging very gradually with posterior straight parts; without scutes; accessory l.l. very short, extending backward for a very short distance only. First dorsal reduced, low with 7–8 spines (number of spines differing with the species and intraspecifically with growth and with the individual, see below); the anterior spines connected by membrane, rather flexible or moderately pungent; the last two spines partly disconnected, short but stout and pungent (relatively longer, slenderer and connected by membrane in the young). Second dorsal with a relatively short, unsegmented, flexible ray in front (probably a spine homologically), and 28–40 segmented rays. Anal similar in structure to second dorsal, with 19–22 segmented rays; preceded by two short, pungent spines, disconnected from rest of fin (the first spine disappearing in the larger specimens of *zonata* and probably also in those of *falcata*). Dorsal and anal lobe well developed or moderate, depending on the species; fold at dorsal and anal base very moderate; dorsal having 7–19 rays more than anal. Ventral rather long, extending more than half the distance from its base to soft anal origin; its outer angle below or slightly in front of lower pectoral angle. Pectoral short, ending in front of a vertical through end of ventral. Caudal subequal to or a little shorter than head.

The preserved, larger specimens of three species here treated are usually of a yellowish golden color, often dusky, with some blackish shades on dorsal, anal and ventral, without specific markings. The smaller specimens have the body with a transversely banded color pattern, and another oblique band in the nuchal region. The size at which the banded pattern disappears differs with the species.

The current systematics of the western Atlantic amberjacks is in a very unsatisfactory state. Jordan (1884, p. 123) gives a key to 7 species of *Seriola* which are said to occur on the east coast of the United States. This treatment is continued by Jordan and Evermann (1896, pp. 901-905) and by Jordan, Evermann and Clark (1930, pp. 279-280). However, based on the evidence hitherto presented and that determined by me not more than 4 species are now definitely known from eastern United States. Hildebrand and Schroeder (1928, p. 218) ascribe only one species to Chesapeake Bay, which they designate *S. dumerili*. They also state that *zonata* and *lalandi* are identical with *dumerili* in the synonymy of which they place those two names. However, this study has shown that *dumerili* and *zonata* constitute two quite distinct species; while the status of *lalandi* must remain uncertain until its type specimen is reexamined in the light of the evidence here presented, but based on its original description the name *lalandi* is likely synonymous with *zonata*. The three specimens which I examined from Chesapeake Bay belong to *zonata* (see its account) rather than to *dumerili*, although it is quite likely that the latter species also occurs in the Bay.

During this investigation, I made a detailed study of all the western Atlantic specimens of *Seriola* available to me which, in the aggregate, constitute a fair composite sample, comprising 89 specimens 97-945 mm. in 64 constituent samples, and 33 specimens 15-86 mm. in 20 constituent samples. One specimen each was taken in the Yucatan Channel, Bermuda, Haiti and Panama, two in Puerto Rico and 3 each in Cuba and in the Bahamas; all others came from eastern United States.

The 89 larger specimens are fairly, though not sharply, divisible into three species which are here named *falcata*, *dumerili* and *zonata*. The three species are fairly distinguishable when the fish reach a length of 300 mm. or so. Specimens about 150-250 mm. are more difficult to distinguish because some of the trenchant specific characters, namely, the shape of the body, caudal peduncle and dorsal and anal fins are as yet undeveloped or not fully developed.

Still smaller specimens, those under 100 mm., are again somewhat easier to distinguish, because of specific differences in the juvenile color pattern, which disappear with growth. The group of 33 small specimens noted above are thus fairly, but not sharply, divisible into 4 species. Four of these specimens 25-60 mm. are definitely referable to *zonata*, as the graded size range examined from these to the larger specimens, is adequate to be certain of their identification. Two specimens 59-70 mm., and 22 specimens 15-69 mm., are here referred to *dumerili* and *falcata*, respectively, with some shade of reservation, as no adequate size range showing the changes from the juvenile to the larger specimens, is available to be altogether certain of their identification. The other 5 specimens 37-86 mm. are here referred to *fasciata*, as they fairly agree with Bloch's figure of his species. All these small specimens are described under the species to which they are tentatively or definitely referred. The characters of those tentatively referred to *dumerili* and *falcata* are given separately in all the accompanying tables, including those giving the frequency distribution of the fin ray counts.

Considering the size and make-up of the composite sample examined it would seem that four and not more than four species of *Seriola* exist on the east coast of the United States anyway. In fact, if more than four species exist in the western Atlantic, better evidence than that hitherto presented will have to be forthcoming to prove it. Of the seven species, recognized by Jordan and his co-workers, as cited above, the names *carolinensis* and *lalandi* are apparently synonyms of *zonata,* while *rivoliana* and *falcata* probably represent corresponding eastern and western Atlantic populations, respectively, as discussed below under the latter.

The number of gill rakers is of considerable value in properly distinguishing the species of *Seriola;* but in using this character it is important to take into consideration its change of growth. In *falcata* the growth change is apparently so small as to be virtually negligible, perhaps one gill raker disappearing with growth occasionally: but in *dumerili* and *zonata* it is considerable. As the fish grows in the latter two species, some of the gill rakers at both ends of the gill arch assume a recumbent position flat against the arch and become reduced to assume the form of low tubercles having a granular surface. Furthermore, with growth similar supernumerary tubercles appear between the gill rakers and between the tubercles representing original gill rakers. Also, the primary and supernumerary tubercles often partly coalesce with one another. The net result is that in the larger specimens of *dumerili* and *zonata* the number of primary tubercles which represent the original terminal gill rakers, is not definitely determinable. As a further consequence, in comparing the number of fairly or well defined gill rakers in the larger specimens of *dumerili* and *zonata* with similar specimens of *falcata*, the divergence is considerable; while in a like comparison of small specimens the extent of divergence between the species is much reduced.

The number of specimens of *dumerili* and *zonata* entered in table 1 is much less than the number examined, because the total number of gill rakers, including primary tubercles, on the first gill arch is not definitely determinable in most specimens examined.

TABLE I

Frequency distribution of the total number of gill rakers, including 1–3 determinable tubercles at ends of arch in four western Atlantic species of *Seriola.*

				distribution				
species and length in mm.	21	22	23	24	25	26	27	28
falcata 164–800	....	....	....	....	2	4	4	....
falcata 37– 69	....	....	....	....	....	4	7	2
fasciata 37– 86	....	....	....	....	3	1	....	1
dumerili 181	....	....	....	1				
dumerili 59– 70	....	1	....	1				
zonata 153–243	7	9	7	....	2			
zonata 41–139	4	5	2					

The number of spines in the first dorsal of *Seriola* is of some value as a species character. It appears to be subject to a moderate degree of individual variability, or to change with growth, depending on the species. In *zonata* 49 specimens 25–620 mm. have 8 spines, and 6 specimens 125–258 mm. have 7 spines (the fin damaged in 6 specimens). In the 8-spined specimens the relative length and thickness of the spines are as follows: the first three spines graduated, the first very low, the third moderately shorter than fourth; the fourth and fifth subequal and longest, stouter than anterior three; the sixth moderately shorter than fifth; the last two short and stout. In *dumerili*, 21 specimens 70–394 mm., have 7 spines, and considering the relative size of the several spines as compared with the 8-spined specimens of *zonata* it is evident that it is the first spine that is missing in *dumerili*. In *falcata* the number seems to differ with growth, the first spine disappearing very early in life, as two specimens 14–15 mm., tentatively identified as *falcata*, have 8 spines, while 30 other specimens 15–800 mm. have 7 spines. In *falcata* also it is apparent that the first spine is the one that disappears. On the other hand, differences in the number of spines of *zonata* appear to be a matter of individual variability. The presence of only 7 spines in the 6 variants of *zonata*, as stated above, evidently is not a growth change. It is not due to the disappearance of the first spine. In two specimens it seems as though the last spine is missing. In the other variants the relative length and thickness of the several spines are somewhat different than in the 8-spined specimens. It is evident that these 6 specimens are individual variants with respect to the structure of the first dorsal; they had only 7 spines to begin with. Finally, five small specimens of *fasciata*, 37–86 mm. have 8 spines, their number and relative sizes being as in most specimens of *zonata*. In sum, it is evident that subject to two limiting factors, individual variability and growth change, the number of spines in the first dorsal is of some value in distinguishing the species.

The species of *Seriola* differ in the size or number of scales. However, in practice it is well nigh impossible to apply this character with any degree of precision, because the scales are small and rather irregularly arranged. For this reason, while the range of the scale counts is given under the accounts of the 4 species and in the key, not much dependence is here placed on these numbers for distinguishing the species; but they are of some limited value in placing specimens near the borderline with respect to other characters. The given counts refer to the number of oblique rows over the lateral line, from its beginning to the caudal base. The range of the scale count given under every species is based on 10 specimens, except 4 specimens in *fasciata*.

The term "preanal" used in the following accounts of the species and in table 2 refers to the distance from the tip of the lower jaw to the base of the first free anal spine or its approximate position when it has disappeared with growth, as in the larger specimens of *zonata*. The height of the dorsal and anal lobes was measured from the base of the flexible spine to the tip of the highest ray, that is, the second or third segmented ray. The height and width of the caudal peduncle was measured at a point just in front of the pit.

TABLE II

Frequency distribution of the preanal distance in four western Atlantic species of *Seriola*, expressed as a percentage of the standard length, segregated by size groups.

species	standard length in mm.	distribution 58	59	60	61	62	63	64	65	66	67	68	69	70	71
falcata	280–408	....	1	4	2	1									
dumerili	266–318	....	....	1	1	2	1	....	....	....	....	....			
zonata	300–370	....	....	....	....	....	....	....	....	....	1	4	5	3	
falcata	132–202	1	....	....	1	....	....	....							
dumerili	148–254	....	....	....	1	6	3	2	2	....	....	....	....		
zonata	149–248	....	....	....	....	....	....	....	....	1	5	4	3	5	1
zonata	81–147	....	....	....	....	....	....	....	1	4	4	9	4	1	....
falcata	29– 56	....	....	....	1	1	1	2	1	2	1	3	1		
fasciata	29– 69	....	....	....	....	....	2	....	2	....	1	....			
dumerili	47– 56	....	....	....	....	....	....	....	....	....	....	....	1	....	1
zonata	20– 50	....	....	....	....	....	....	....	....	....	....	1	1	1	1

As the species of *Seriola* change markedly with growth, specimens have to be compared size for size in order to distinguish the species properly. The following accounts are based almost exclusively on specimens 500 mm. or smaller, and will most probably not apply altogether to very large specimens. One specimen 945 mm. for which no comparative material is available, is treated separately under the account of *dumerili*. Two skinned specimens about 565 and 880 mm. long, belonging to *dumerili* and *falcata*, respectively, are included in their accounts. As no proportional measurements could be determined for the latter two specimens, they were identified by their counts and general appearance.

TABLE III

Frequency distribution of the height of the soft dorsal lobe in four western Atlantic species of *Seriola*, expressed as a percentage of the standard length.

species	standard length in mm.	distribution															
		13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
falcata	280–408										2	1	1	2	1		1
dumerili	266–318	....	2	1	2	....	....	....	....	....	....	....	....				
zonata	300–370	....	2	6	5	....	....	....	....								
falcata	132	....	....	....	....	....	....	....	1								
dumerili	148–254	1	1	6	6												
zonata	149–248	....		5	4	7	2										
zonata	81–147	....	....	....	5	7	7	4									
falcata	29– 56	....	....	....	....	....	2	2	3	3	2						
fasciata	29– 69	....	....	....	....	....	1	3	....								
dumerili	47– 56	....	....	....	....	....	....	....	2								
zonata	20– 50	....	....	....	....	....	1	....	3								

Under the following accounts of the species. I have attempted to give some of the more important references. especially references to synonyms. The segregation of these references by species has been made on the basis of the published accounts, except in three instances where the specimens on which the records are based have been reexamined. The synonymies here given are of a highly tentative nature for two reasons. First. published descriptions. in general, are inadequate and it is uncertain as to what species a given author had before him. The species are very close in their structural characters. and current descriptions either omit or do not give the pertinent specific characters in sufficient detail to identify the particular species with certainty. Besides, growth changes within the species are pronounced, and until such changes are better known the status of species based on small specimens must remain in doubt. Second, the synonymies here given are based on the assumption that only four species of the genus exist in the western Atlantic. which as yet cannot be regarded as definitely established. Ordinarily. it would not seem advisable to try to establish synonymies on the basis of such inadequate data. However, in this instance it is thought that these tentative synonymies will be of some help in the further study of the western Atlantic species of *Seriola*. If it is eventually proved that more than 4 species occur in the western Atlantic. some of the names here placed in synonymy will likely have to be resurrected. Also. it is very possible that the given synonymies will have to be rearranged after an examination of such specimens as are still in existence, on which the published records are based.

Seriola is very close to *Naucrates* Rafinesque which differs primarily in having the first dorsal still further reduced. *Naucrates ductor* has the caudal peduncle depressed as in *Seriola zonata*. The body is slenderer on the average and the keel on the caudal peduncle somewhat better developed than in *S. zonata;* while the dorsal and anal rays average less than in *S. falcata*. *Seriola* differs from *Elagatis* in lacking a separate finlet behind the dorsal and anal. Otherwise, these three genera are readily distinguished from the other carangids here treated by the combination of characters given in the key.

TABLE IV

Frequency distribution of the height of the anal lobe in three western Atlantic species of *Seriola*. expressed as a percentage of the standard length.

species	standard length in mm.	distribution 10	11	12	13	14	15	16	17	18	19	20
falcata	280–408	....	....	....	....	..	....	....	....	4	3	1
dumerili	266–318	....	....	1	2	2	....	....	....	....	....	....
zonata	300–370	1	3	6	3		. .		.	. .	.	.
falcata	132–202	....	....	....	....	....	1	....	1	.	. .	.
dumerili	148–254	....	....	2	10	1	1	.	. .	.	. .	.
zonata	149–248	....	....	9	8	2	.	. .	....	. .	....	..
zonata	81–147	....	....	7	14	2	. ..	....	....	.. .	....	....

Seriola falcata Cuvier and Valenciennes

Falcate amberjack, Plate 1, fig. a; Plate 2, figs. a and c

Seriola falcata Cuvier and Valenciennes. Hist. Nat. Poiss. 9:210, 1833 (Gulf of Mexico).—Jordan and Gilbert, Proc. U. S. Nat. Mus. 5:271, 1882 ("Snapper Bank at Pensacola").—Jordan and Evermann, Bull. U. S. Nat. Mus. 47(1): 905. 1896 ("West Indies, north to Florida and Carolina")

Seriola boscii Cuvier and Valenciennes, Hist. Nat. Poiss. 9:209, 1833 (Carolina; based on small specimen)

Seriola bonariensis Cuvier and Valenciennes, ibid., p. 211. 1833 (Buenos Aires).—Goode and Bean, Proc. U. S. Nat. Mus. 2:48, 1879 (Pensacola; reexamined)

Seriola declivis Poey, Mem. Hist. Nat. Cuba 2:230, 1860 (Cuba)

Seriola ligulata Poey, ibid., p. 231 (Cuba)

Seriola coronata Poey, ibid., p. 232 (Cuba)

D VII (VIII): I 28–32. A (I) II; I 19–22. P. 19–22. GR 7–8+16–18. Sc 122–137.

TABLE V

Frequency distribution of body depth measured at origin of soft dorsal in four western Atlantic species of *Seriola*, expressed as a percentage of the standard length.

species	standard length in mm.	distribution 24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
falcata	280–408	....	....	....	....	....	....	....	....	....	....	....	2	3	1	1	....	1	....
dumerili	266 318									1	1		3						
zonata	300–370	2	1	...	2	3	4	1	....	....	....	....	....	....	....	....	....	....	....
falcata	132–202	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	1	....
dumerili	148–254	....	....	....	....	....	....	1	3	2	1	5	1	....	1	....	....	....	....
zonata	149–248							2	3	3	6	5	1	1					
zonata	81–147	....	....	....	....	....	....	2	2	2	5	8	3	1	....	....	....	....	....
falcata	29– 56	....	....	....	....	....	....	....	....	....	....	....	....	1	..	6	2	1	3
fasciata	29– 69	. ..	....	....	....	....	....	....	....	....	....	....	....	....	1	....	1	1	.
dumerili	56	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....
zonata	20– 50	....	....	....	....	....	....	....	....	1	1	2	....	....	....	....	....	....	....

Anal fin not placed notably backward, preanal 59.5 62.0; dorsal and anal lobes comparatively high, 21.5–27.5 and 18–20, respectively; body deep (for a *Seriola*), 34.5–40.0; caudal peduncle compressed, the keel very moderate or hardly perceptible; depth at posterior margin of head subequal to its length or slightly more, head 29.0–30.5, depth at its posterior margin 29.0–32.5. Gill rakers on upper limb 7–8, on lower limb 16–18, usually with one tubercle-like outgrowth at anterior end, sometimes 2 or 3 tubercles; total number of gill rakers and tubercles on both limbs 25–28. Dorsal spines 7 (in 11 specimens 164–800 mm.; dorsal spines 8 in very small specimens and gill raker count nearly the same in large and small specimens, see below). First disconnected anal spine present (absent in one large specimen, see below). Without dark bands.

Table VI

Frequency distribution of the depth at posterior margin of opercle in four western Atlantic species of *Seriola*, expressed as a percentage of the standard length.

ies	standard length in mm.	distribution 23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
cata	280–408	....	....	....	....	....	....	3	1	2	2									
nerili	266 318						1	2	1	1										
ata	300–370	3	1	3	5	1	....	....	....	....	....	....								
rata	132–202											1		1						
nerili ...	148–254	....	....	....	1	1	1	2	6	1	2	....	....	..						
ata	149–248	....	....	1	2	1	3	6	4	1	1									
ata	81–147					1	2	7	5	6	2									
cata	29– 56	....	....	....	....	....	....	....	....	....	....	....	....	....	2	3	6	....	1	1
ciata	29– 69													2		1	1		1	
nerili	56	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	
ata	20– 50	....	....	....	....	....	....	....	....	....	....	2	1	1						

The above description is based on 8 specimens 350–500 mm. Two specimens 164–245 mm. nearly agree, except in having a wide, oblique, black band running from eye to origin of first dorsal. Their measurements are given separately in tables 1 6. One skinned specimen, about 880 mm., nearly agrees with the above description in its determinable characters, except that the first anal spine is absent at the surface.

Twenty-two specimens examined, 15–69 mm., are tentatively referred to this species, as no graded size range to the larger specimens is available to make this identification altogether certain. Their fin ray counts are given separately in tables 8 9. Two specimens 15 16 mm., have 8 spines in the first dorsal; the other 20 specimens 15–69 mm., have 7 spines. All have the two anterior anal spines well developed. The measurements of 13 specimens 36 69 mm. are given separately in tables 2 3 and 5–6. The gill rakers are rather well developed, and number in the latter 13 specimens 7-9+18–20, except that one specimen has a tubercle at the end of the lower limb in addition to 18 well developed gill rakers; total number on both limbs 26 28, including the tubercle. Six specimens 15 21 mm. have no bands, one specimen 23 mm. has faint bands, while the other 15 specimens 31 69 mm., have dark bands, as follows: an oblique band on nape running from posterior margin of eye to origin of first dorsal; body with cross bands, usually 5 bands, the first directly behind head narrower than others, the fifth a little in front of end of dorsal and anal fins; sometimes with six bands on one or both sides, the sixth band at end of dorsal and anal fins; occasionally a faint trace of a band at caudal base. The body bands are not solidly colored, a lighter narrow, irregular area running transversely along their middle.

Specimens examined from or off the following localities: Georgetown, S. C., (151949). Fla. (26591). Clearwater, Fla. Pensacola, Fla. (22901). Mississippi Delta, La. Bermuda (21391). Watling Island, Bahamas (38423). Cuba (12539). Port au Prince, Haiti (133682). Colon, Panama (148913). Altogether 10 specimens 164–500 mm. Also, one skinned specimen about 800 mm. from Pensacola, Fla. (22258). Localities for the 22 small specimens tentatively referred to this species, as described above: eastern United States (106279). Cape Charles, Va. (131934). Cape Hatteras (83771) and Beaufort (105863, 106152–3, 106278, 106420), N. C. Tortugas, Fla. (88092). Puerto Rico (117871).

TABLE VII

Frequency distribution of the ratio of the depth of the caudal peduncle divided by its width at the same point, just in front of the pit, in three western Atlantic species of *Seriola*.

species	standard length in mm.					distribution						
		0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7
falcata	280–408	....	....	....	...	....	....	2	2	3	1	
dumerili	266–318	..	....	....	2	1	1	1				
zonata	300–370	1	4	5	3							
falcata	132–202	....	....	....	....	....	....	....	1			1
dumerili	148–254	....	....	....	1	4	1	2	4	2		
zonata	149–248	....	2	4	7	6	1	..	1			
zonata	81–147	....	...	1	7	8	5	1	....	1		

The larger specimens of *falcata* differ from both *dumerili* and *zonata* in having the dorsal and anal lobes markedly higher. They further differ from similar specimens of *zonata* in having a shorter preanal distance. a deeper body and a compressed caudal peduncle.

TABLE VIII

Frequency distribution of the number of segmented dorsal rays in four species of *Seriola*.

species and length in mm.							distribution							
		28	29	30	31	32	33	34	35	36	37	38	39	40
falcata	164–880	3	2	6	....									
falcata	15– 69	4	3	4	7	4				....				
fasciata	37– 86	....	....	1	1	2								
dumerili	181–394	....	....	2	3	6	6	2	2					
dumerili	59– 70	....	....	....	1	1	...	....	....	....	....	....	....	....
zonata	41–514	....	....	....	....	....	1	7	10	21	11	7	2	1

The gill rakers in the larger specimens of *falcata* number 7–8+16–18; while the number of well defined gill rakers in similar specimens of *dumerili* and *zonata* is 2 3+ 11–13. This difference is also one of development. Both *dumerili* and *zonata* have an increased number of gill rakers in the smaller specimens. With growth some of the gill rakers, at both ends of the gill arch, become so reduced and coalesced with the arch and with one another that their number is not definitely determinable, as discussed under the genus. In *falcata*, on the other hand, this growth change is slight, and as a consequence the larger specimens are rather well separable from *dumerili* and *zonata* on the basis of the gill raker count. In small specimens the gill raker count of *falcata* does not diverge as widely from the other two species.

This species averages the lowest dorsal count. It does not intergrade with *zonata* in this character, but it does so with *dumerili*. Its scale count is also low as compared with the other two species; but the latter character is difficult to apply in practice, as the scale count is not determinable with a high degree of precision.

TABLE IX

Frequency distribution of the number of segmented anal rays and the number of pectoral rays in four western Atlantic species of *Seriola*.

	anal rays				pectoral rays						
species and length in mm.	19	20	21	22	16	17	18	19	20	21	22
falcata 164–880	2	1	8	....	....	....	....	....	2	6	3
falcata 15– 69	2	8	11	1	....	....	....	1	3	9	2
fasciata 33– 86	2	1	...	....	....	....	....	1	4		
dumerili 181–394	2	10	7	2	....	....	....	1	3	16	1
dumerili 47– 56	....	2	....	....	....	....	....	....	1	1	
zonata 25–514	16	33	11	..	1	...	3	18	32	7	

Nomenclature.—A specimen from the Azores (94489), presumably an example of *rivoliana*, 236 mm. in standard length, measures the dorsal and anal lobes 19.0 and 16.5, while in 9 specimens from the western Atlantic 202–408 mm., the same two measurements are 20.5–27.5 and 17.5–20.0, respectively. The well marked lobes in the western Atlantic specimens as compared with the one from the eastern Atlantic, are more striking in appearance than the measurements would indicate. It is also possible that *rivoliana* averages a shorter ventral than *falcata*, as the ventral length in the above one and nine specimens is 18.5 and 18.5–20.5, respectively. While the samples compared are inadequate to draw definite conclusions, it is probable that these corresponding eastern and western Atlantic populations diverge sufficiently to constitute distinct species or subspecies. Therefore, I apply the name *falcata* which is based on specimens from the Gulf of Mexico, to the western Atlantic population.

Seriola fasciata (Bloch)

Little amberjack, Figure 1; Plate 2, fig. e

Scomber fasciatus Bloch, Ichthyologie ou Histoire Naturelle des Poissons pt. 10, p. 61, pl. 341, 1797 (locality unknown)

Seriola semicoronata Poey, Mem. Hist. Nat. Cuba 2:232, 1860 (Cuba)

D VIII; I 30–32. A II; I 19–20. P 19–20. GR 7–8+18–20. Sc. 129–134.

The following description of this species is not strictly comparable with those of the other 3 species, as it is based on small specimens only, 37–86 mm., while the specific characters of the species of *Seriola* change markedly with growth. Its comparison with the small specimens of the other species is best made in the accompanying tables.

Anal fin not placed notably backward, preanal 62.5–67.5; dorsal lobe 18.0–19.5; anal lobe 14.5–16.5; depth 37–42; caudal peduncle compressed, without a keel (same holds for small specimens of other 3 species); depth at posterior margin of head greater than its length or subequal to it, head 33.0–37.5, depth at its posterior margin 35–40. Gill rakers rather well developed 7–8+18–20, or 25–28 in total count. Dorsal spines 8. Both anterior anal spines well developed. Body typically with 8 cross bands, the seventh at end of dorsal and anal fins, the eighth on caudal peduncle; most bands usually well divided by a transverse median irregular lighter area; sometimes the lighter area very wide, leaving only the narrow margins of the bands, such variants having appearance of a cross-streaked pattern with the streaks arranged roughly in pairs; nuchal band solidly pigmented, moderately oblique, extending from eye upward and somewhat backward, not quite reaching origin of first dorsal.

Specimens examined from off the following localities: Long Island, N.Y. (35573). Cape Charles, Va. (157569). Beaufort, N.C. (105862). Tortugas, Fla. (116868). One specimen taken by the Fish Hawk, without data, evidently collected in the western Atlantic and most likely on the coast of the United States. Total examined 5 specimens 37–86 mm.

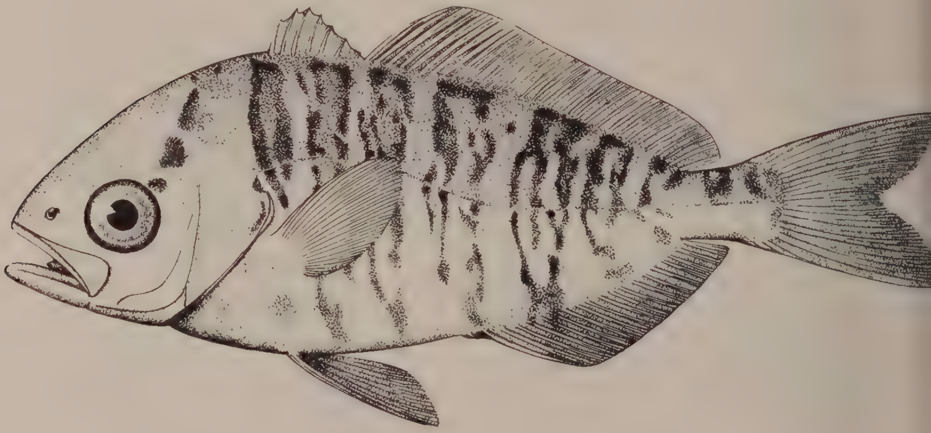


FIGURE 1

Seriola fasciata, 46.6 mm in standard length, about 58 mm long. Albatross Station 2047, lat. 40° 02′ 30″ N, long. 68° 49′ 40″, off Long Island, N. Y., at the surface. USNM 33573.

The 5 small specimens examined of this species fairly agree in their counts and measurements with 22 similar specimens of *falcata*, except in having 8 dorsal spines, instead of 7, and in the color pattern. The nuchal band is not as oblique as in *falcata*, the body bands are more numerous, and the median lighter area within the bands is usually wider. This species differs from *dumerili* and *zonata* in having more gill rakers. It is possibly a small species. A larger example of this species was not found among the many specimens examined. Bloch does not give the size of his specimens, but the *semicoronata* of Poey which seems to be a synonym of *fasciata*, is based on a specimen 240 mm.

Nomenclature.—Bloch's figure of his *fasciata* shows a moderately oblique nuchal band, and the body bands split transversely in an irregular manner. Allowing for individual variability and the rather crude nature of the illustrations published by Bloch and his contemporaries, his figure seems to have been made from a specimen of the same species as the 5 specimens described above, and the name *fasciata* is, therefore, applied to these specimens.

Seriola dumerili (Risso)

Great amberjack, Plate 1, fig. b

Caranx dumerili Risso. Ichthyologie de Nice. p. 175. pl. 6. fig. 20. 1810 (Mediterranean)

Seriola dumerili Cuvier and Valenciennes. Hist. Nat. Poiss. 9:201. 1833 (Mediterranean).—Jordan. Proc. U. S. Nat. Mus. 7:122. 1884 (Key West).—Jordan and Evermann. Bull. U. S. Nat. Mus. 47(1):903, 1896 ("Mediterranean to West Indies, north to Key West and Pensacola").—Gunter and Knapp, Texas Jour. Sci. 3(1): 136, 1951 (Port Aransas, Texas)

Seriola gigas Poey, Mem. Hist. Nat. Cuba 2:227, 1860 (Cuba)

Seriola proxima Poey, ibid. p. 229 (Cuba)

Seriola lalandi Jordan and Gilbert. Proc. U. S. Nat. Mus. 5:271, 1882 (Pensacola)

Seriola zonata Jordan and Evermann (in part), Bull. U. S. Nat. Mus. no. 47(4), pl. 139. fig. 381, 1900 (specimen forming basis of figure reexamined, belonging to this species)

D VII; I 30–35. A II; I 19–22. P 19–22. GR 2–3+11–13. Sc. 141–163.

Anal fin not placed notably backward. preanal 60–63; dorsal and anal lobes moderate. 14–16 and 12.5–13.5. respectively; body moderately deep 32–35; caudal peduncle compressed to subterete. the keel moderate or very slight; depth at posterior margin of head subequal to its length. varying slightly both ways. head 29.5–30.0, depth at its posterior margin 28.5–31.0. Well developed gill rakers 2–3+11–13. Dorsal spines 7 and first disconnected anal spine present (in 21 specimens examined 70–394 mm.).

The above description is based on 5 specimens 327–394 mm. which are approximately comparable with the larger specimens described of *falcata* and *zonata*. Fourteen specimens 181–320 mm. show slight or moderate differences in proportional measurements as compared with the larger specimens, as shown in tables 2–7.

One large specimen. 945 mm.. from Woods Hole (44167), has the following counts and measurements: D VI; I 33. A II; I 20. P 21. GR 2+11. Scales 160. Standard length 790 mm. Preanal 62, depth at soft dorsal origin 25, depth at opercular margin 24, dorsal lobe 13, anal lobe 13, width in depth of caudal peduncle 1.1 times. The last dorsal spine has disappeared and the first of the two detached anal spines is barely appreciable at the surface. In the preanal distance and the shape of the caudal peduncle. this specimen agrees with *dumerili*. Its dorsal and pectoral counts fall at the mode of *dumerili*. and at the extremes of the distributions of *zonata*. In its depth measurements it agrees with specimens of *zonata* 300–370 mm., as shown in tables 5–6. Also. the keel on the caudal peduncle is fairly developed as in the above specimens of *zonata*. As the latter characters change with growth in the species of *Seriola*. and in other carangid species as well the best conclusion that we may come to now. in the absence of comparative specimens of similar size. is that this large specimen is an example of *dumerili*. That is. in *dumerili*, as in *zonata*. the relative depth decreases and the peduncular keel becomes more prominent in large specimens. The fin ray counts of this specimen are included in the accompanying tables, but not its measurements.

Two specimens 59–70 mm. are tentatively referred to *dumerili*, as no adequately graded size range is available to be altogether certain of their identification. Their counts and measurements are given separately in the tables. The gill raker count in the two specimens is 7+15–17, including one tubercle at one or both ends of the gill arch.

One specimen 181 mm. has the gill raker count 6+18 including 4 tubercles at the anterior end of the arch. This is the specimen entered in table 1. In the other specimens 209 mm. or longer, the number of primary tubercles at one or both ends of the gill arch is not definitely determinable as discussed under the account of the genus.

Specimens examined taken at or off the following localities: Acushnet River (82251) and Woods Hole (18720, 44944, 50580, 77797, 104999 and 125698), Mass. Wickford. R.I. (38114). Brooklyn, N.Y. (4608). Ocean City, Md. (76692). Pensacola, Fla. (22902). Bahamas (4653 and 53119). Cuba (82415). Venice (28450) and Bay of Naples (48319), Italy. Altogether 19 specimens 181–394 mm. Also, one skinned specimen about 565 mm. from Havana, Cuba (35064), agrees in its counts (D VII: I 34. A II; I 21. P 21; included in the tables), and general appearance with *dumerili*. Localities for the 2 small specimens tentatively referred to this species, as discussed above, are: Yucatan Channel (142886; 59 mm.; in bad condition having been dried at some time in past, some measurements not accurately determinable and no trace of color pattern left; first dorsal damaged or abnormal). Puerto Rico (108415; 70 mm.; color apparently nearly all faded, with only slight traces of cross bands).

In the number of dorsal rays and scales and the body depth of the larger specimens, *dumerili* is rather intermediate between *falcata* and *zonata*, intergrading with both in the dorsal ray count, and possibly also in the other two characters. It nearly agrees with *zonata*, and differs from *falcata* in the comparatively low dorsal and anal lobes. It nearly agrees with *falcata* and differs from *zonata* in the relatively shorter preanal distance. In the larger specimens the number of well defined gill rakers nearly agrees with *zonata*, and differs considerably from *falcata*.

Seriola zonata (Mitchill)

Slender amberjack; banded rudderfish (young). Plate 1. fig. c; Plate 2. figs. b and d

Scomber zonatus Mitchill, Trans. Lit. Philos. Soc. New York 1:427, pl. 4, fig. 3. 1815 (New York Bay)

Seriola zonata Holbrook. Ichthyology of South Carolina. p. 73. pl. 10. fig. 1. 1855 (South Carolina).—Jordan and Evermann (in part). Bull. U. S. Nat. Mus. 47(1): 902, 1896 (Cape Cod to Cape Hatteras: the published figure executed from a specimen of *dumerili*, reexamined)

Seriola lalandi Cuvier and Valenciennes. Hist. Nat. Poiss. 9: 208. 1833 (Brazil: the statement "les côtés de la queue sont relevés en une carè prononcée." describes the typical condition of large specimens of *zonata*).—Jordan. Proc. U. S. Nat. Mus. 7: 122, 1884 (Key West).—Jordan and Evermann. Bull. U. S. Nat. Mus. 47(1): 903, pl. 140, fig. 382, 1896 ("West Florida to Brazil"; a mounted specimen on exhibition in the National Museum, which probably formed the basis of Jordan and Evermann's figure appears to be a specimen of *zonata*)

Seriola leiarchus Cuvier and Valenciennes, l. c., p. 213 (sent from Philadelphia by LeSueur)

Seriola carolinensis Holbrook. Ichthyology of South Carolina. p. 70. pl. 10. fig. 2. 1855 (South Carolina).—Holbrook. Ichthy. S.C., ed. 2, p. 72, pl. 10. fig. 2 (plate in second edition more nearly resembling *zonata* than that in first edition)

Seriola dubia Poey, Mem. Hist. Nat. Cuba 2: 228, 1860 (Cuba)

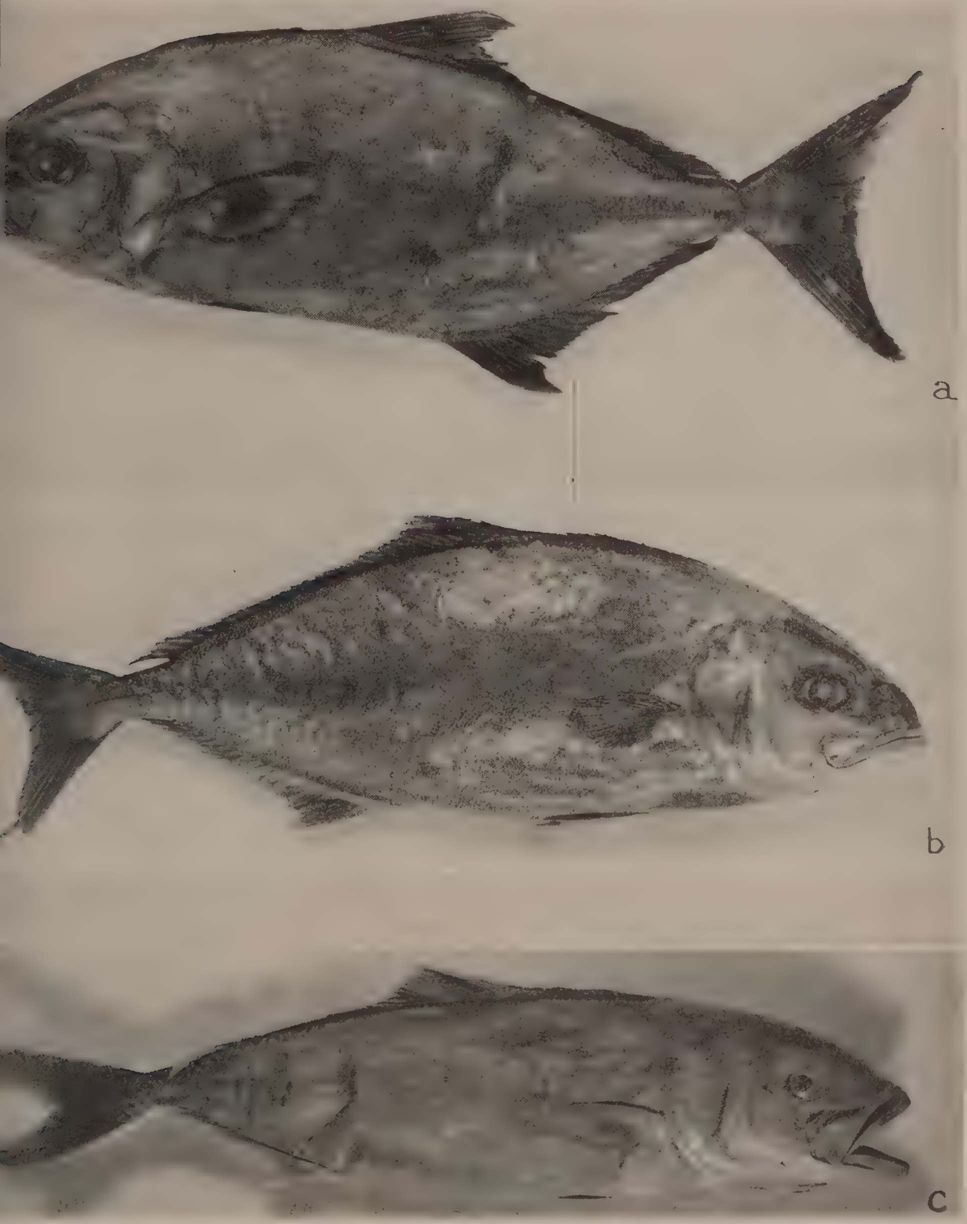


Plate 1

Fig. a. *Seriola falcata*, 321 mm Pensacola, Fla. USNM 22901.

Fig. b. *Seriola dumerili*, 318 mm in standard length, about 390 mm long. Woods Hole, Mass. USNM 18720.

Fig. c. *Seriola zonata*, 328 mm in standard length, about 400 mm long. Charleston, S. C. USNM 4606.

Seriola stearnsi Goode and Bean. Proc. U. S. Nat. Mus. 2: 49, 1879 (Gulf of Mexico; reexamined).—Jordan and Gilbert. ibid. 5: 270. 1882 (Snapper Banks about Pensacola)

D VII–VIII; I 33–40. A I(II); I 19–21. P(16) 18–21. GR 2–3+11–13. Sc 160–187. Anal fin placed notably backward. preanal 67.0–69.5; dorsal and anal lobes moderate, 14.0–16.5 and 10.5–13.0, respectively; body rather slender, depth 24–30; caudal peduncle usually depressed, sometimes subterete, the keel rather well developed; depth at posterior margin of head less than its length, head 29–32, depth at its posterior margin 22.5–26.5. Well developed gill rakers 2–3+11–13; rudimentary ones at both ends of arch not definitely determinable. Dorsal spines usually 8, sometimes 7 as an individual variation (see discussion under genus). First disconnected anal spine absent at the surface. Without bands.

The above description is based on 14 specimens 362–620 mm. Small specimens have a striking, banded color pattern as follows. Body with 6 cross bands, the first directly behind head, the fifth a little in front of end of dorsal and anal fins, the sixth on caudal peduncle; the bands uniformly pigmented, subequal in width to interspaces, continued on second dorsal and anal and becoming oblique in position on fins; a similar oblique band from eye to origin of first dorsal. The banded pattern is evident but not sharply marked in a specimen of 25 mm. (perhaps faded), is well marked in specimens 41 mm. up to about 220 mm., fades out and disappears between 220 and 260 mm.

Both the head length and the depth at its posterior margin are greater in the smaller specimens, but the increase in depth is relatively greater. In 11 specimens 122–199 mm. depth at posterior margin of head moderately less than, or subequal to its length, head length 30.5–34.0, depth at its posterior margin 28.5–32.0. Other changes in proportional measurements in the smaller specimens are shown in tables 2–7. Another growth change refers to the visual disappearance of the first pungent anal spine. Both detached anal spines are present in 42 specimens 25–254 mm., and 3 specimens 277–299 mm.; but the first spine is absent at the surface in 13 specimens 362–620 mm., and 3 specimens 258–296 mm.

The number of primary tubercles on the first gill arch, as discussed under the account of the genus, is countable in specimens up to about 245 mm., but sometimes not definitely determinable in specimens as small as 180 mm. The determinable specimens are entered in table 1.

Specimens examined from or off the following localities: North Truro (48909) and Woods Hole (12997, 14056, 14808, 16513, 20490, 49605, 58897, 70346, 73485 and 125668). Mass. Newport, R.I. (25712). Atlantic City (45201–2) and Seaside Park (93929). N.J. Havre de Grace (85554) and Ocean City (76696). Md. Cape Charles (42448–9). Willoughby Point (25634) and Cape Henry (16748). Va. Cape Hatteras (53118). Cape Lookout (74288–9, 74296) and Beaufort (106292). N.C. Georgetown (151944) and Charleston (4606, 24680, 25169 and 127214). S.C. Clearwater. Fla. Pensacola, Fla. (22325, type of *stearnsi*). Eastern United States (106279). Washington, D.C. market (92400). No locality (16799, one specimen). Total examined 62 specimens 25–620 mm., in 38 constitutent samples. The largest is from Pensacola.

The larger specimens of *zonata* differ from *falcata* and *dumerili* in the longer preanal distance. They nearly agree with *dumerili* and differ from *falcata* in the moderate dorsal and anal lobes and the gill raker count. As compared with the other two species. *zonata* is notable in usually having a depressed caudal peduncle, a well marked peduncular keel, a slender body and high dorsal ray and scale counts. In the latter characters it is rather discontinuous as compared with *falcata*, but approaches to or somewhat intergrades with *dumerili*. It further differs from those two species in usually having 8. instead of 7 dorsal spines (see discussion under genus).

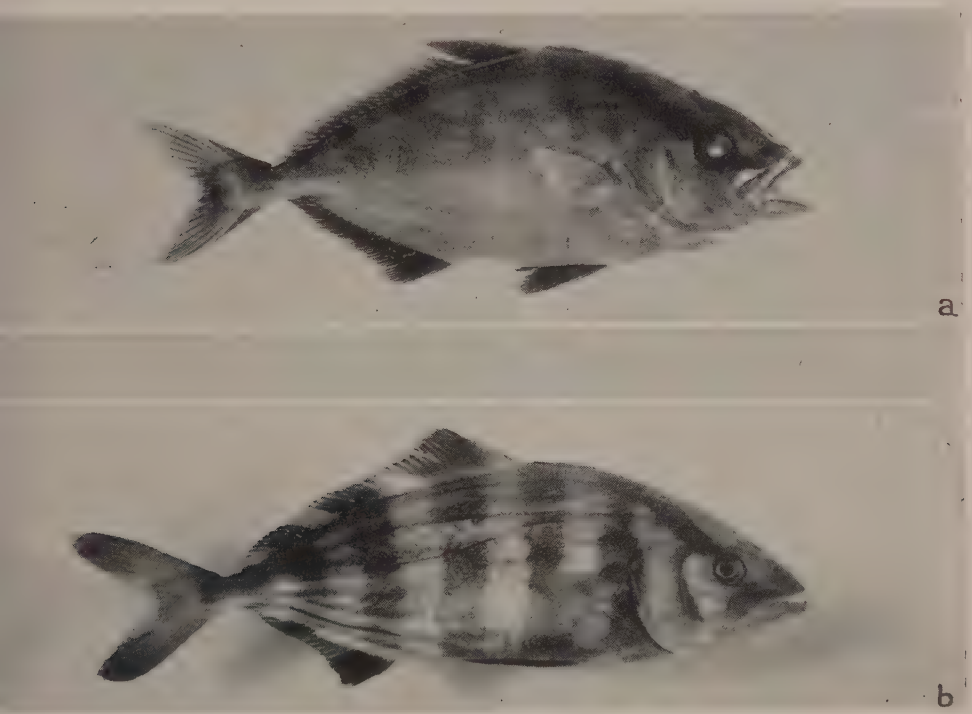


Plate 2

Fig. a. *Seriola falcata*, 164 mm Clearwater, Fla. USNM 157564.
Fig. b. *Seriola zonata*, 179 mm Woods Hole, Mass. USNM 70346.

ELEGATIS Bennett

Elagatis Bennett. Narrative of a whaling voyage around the globe, vol. 2. p. 283, 1840 (genotype *Elagatis bipinnulatus* Bennett by monotypy).

This genus nearly agrees with *Seriola* in the characters studied, but differs in having a separate finlet behind the dorsal and anal. only 6 dorsal spines. and a notably greater number of gill rakers.

Elagatis bipinnulatus (Quoy and Gaimard)

Rainbow runner

Seriola bipinnulata Quoy and Gaimard, Voy. Uranie, p. 363, pl. 61, fig. 3, 1824 (Papua)

Elagatis bipinnulatus Bennett, Narrative of a whaling voyage round the globe, vol. 2, p. 283, fig., 1840 ("Examples came under our notice in the Pacific Ocean and Indian Archipelago, from lat. 6° N. to 8° S. They were very numerous around a log of drift-wood, on the Equator, in long. 140° E., as well as in the Straits of Timor." *E. bipinnulatus* described as a new species without reference to Quoy and Gaimard).—Jordan and Evermann. Bull. U. S. Nat. Mus. 47(1): 906, 1896 (Long Island).- Nichols and Breder, Zoologica 9: 109, fig. 145. 1926 (New York).—Gunter and Knapp. Texas Jour. Sci. 3: 136. 1951 (off Port Aransas)

Seriolichthys bipinnulatus Gunther, Cat. Fish. Brit. Mus. 2:468, 1860 (Amboyna)

Seriola pinnulata Poey, Mem. Hist. Nat. Cuba 2: 233, 1860 (Cuba)

D VI; I 25–26; 2. A O–II; I 16–17; 2. P 20–21. GR 10–11+25–26.

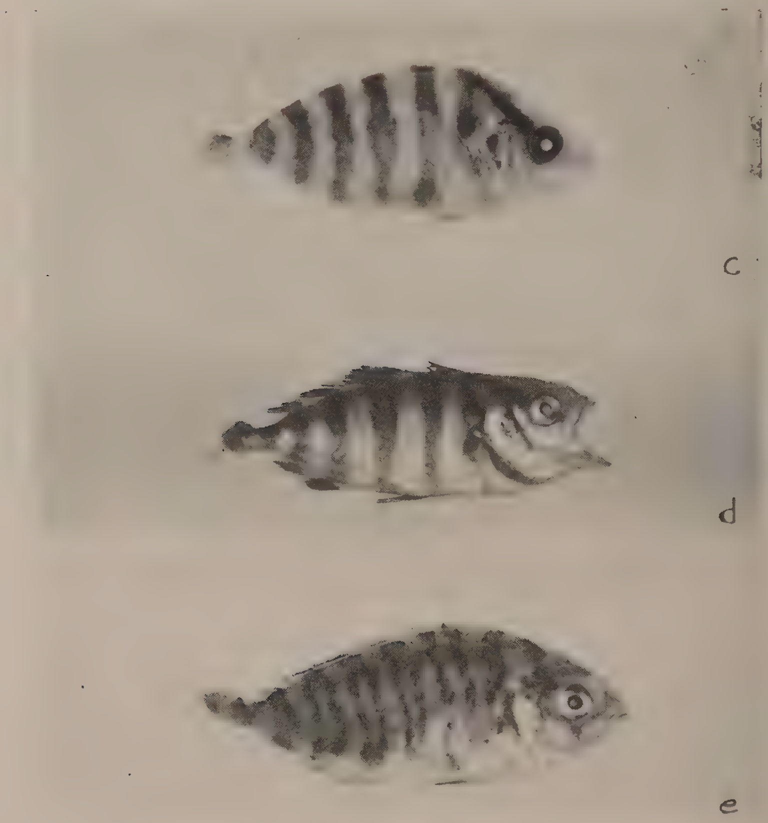


Plate 2—(Continued)

Fig. c. *Seriola falcata,* 69 mm Beaufort, N. C. USNM 106153.

Fig. d. *Seriola zonata,* 50 mm in standard length, about 60 mm long. Woods Hole, Mass. USNM 58897.

Fig. e. *Seriola fasciata,* 79 mm Collected by the Fish Hawk, apparently in the western Atlantic and very likely on the coast of the United States, precise locality unknown. USNM 157565.

Spindle shaped, slender; caudal peduncle rather wide (for a carangid), the keel but slightly indicated. Snout rather long, moderately tapering. Adipose eyelid fairly developed posteriorly, slightly so anteriorly. Maxillary ending at a considerable distance before eye (to under anterior margin of eye in small specimens); moderately broadening posteriorly; supplemental maxillary comparatively narrow. Mouth rather small, terminal, jaws subequal in front. Teeth subequal, in bands of moderate width in jaws, tapering, becoming narrow, posteriorly; in a roughly triangular, rather large patch on vomer, tapering moderately backward for a moderate distance; in a rather wide band on palatines and tongue. Anus placed near normal position of first anal spine. Scales small; scales on antedorsal area extending to a vertical between preopercular margin and eye; cheek and upper part of opercle scaled, greater part of opercle and rest of head scaleless; caudal scaled, other fins scaleless. Anterior curve in lateral line very low, continued imperceptibly into posterior straight part; scales in l.l. not scutelike; accessory l.l. extending for a short distance, falling short of a point opposite preopercular margin, marking boundary of scaled part on dorsal aspect. Spinous dorsal rather low, with 6 spines connected by membrane, last one partly so, the anterior spines rather flexible. First anal spine disappearing at the surface at about 200 mm., second also disappearing in the larger specimens. Dorsal and anal lobes rather low: fold at the base of fins moderate anteriorly, absent posteriorly; dorsal having 9 more rays than anal; behind each fin a detached finlet, spaced for some distance and having 2 rays. Ventral short, extending less than half the distance from its base to soft anal origin, its outer angle under lower pectoral angle. Pectoral short, ending in front of a vertical through end of ventral. Caudal longer than head.

TABLE X

Frequency distribution of the number of dorsal spines and rays in four species of *Trachinotus*.

	spines*		segmented rays									
species	6	7	18	19	20	21	22	23	24	25	26	27
falcatus	....	24	1	16	7							
glaucus	...	39	....	23	16	....				....		
marginatus	....	7	....	2	4	1	....	....	....	....	....	
carolinus	51	295	....	....	....	....	....	36	183	110	12	1

*As the spinous and soft dorsal are continuous in young specimens, all the dorsal spines, the one which becomes with growth part of the second dorsal as well, are included in the count, the data referring to both small and large fish.

The preceding description is based on two specimens, one each from "Florida" (4609) and Port au Prince, Haiti (133678). Gunter (above synonymy) records this species from the coast of Texas.

This species and *Decapterus punctatus* are the only Gulf species of the family Carangidae, which have a detached finlet behind the dorsal and anal fins, but otherwise the two species are not closely related. It differs from *D. punctatus* strikingly in lacking scutes in the lateral line, and in other characters, as may be gathered by comparing their accounts. Structurally this species is near *Seriola* as stated under its genus.

TRACHINOTUS Lacépède

Trachinotus Lacépède, Hist. Nat. Poissons 3: 78, 1802 (genotype *Scomber falcatus* Linnaeus by monotypy)

Deep to very deep depending on the species and stage of growth; well compressed: rather asymmetrical, apex of ventral contour placed a little more backwards than that of dorsal profile; peduncle deep (for a carangid) and compressed. Snout having a characteristic aspect, short, obtuse, its anterior profile nearly vertical. Adipose eyelid very moderately developed. Maxillary of very moderate width, short, ending under middle of eye, varying a little both ways; an elongate groove setting off an upper, posterior part of maxillary resembling a supplemental maxillary in shape, but without an evident suture along the groove. Mouth small, moderately inclined, subinferior, lower jaw moderately included. Teeth small; in narrow bands in jaws, that in lower jaw somewhat wider, disappearing with growth in *carolinus* and *falcatus*, persistent in *glaucus* and *marginatus;* present on head of vomer and palatines in *falcatus, glaucus* and *marginatus*, absent in *carolinus*, with growth disappearing in medium-sized specimens of *falcatus* and becoming reduced in *glaucus* and *marginatus;* absent on shaft of vomer; present in a rather narrow band on tongue in *falcatus* (disappearing in large specimens), absent in *carolinus, glaucus* and *marginatus*. Pseudobranchiae moderately developed in young, disappearing with growth (the only carangid genus here treated lacking pseudobranchiae). Gill rakers on upper limb 5–9, gradually decreasing in length at attached end, or 1–4 at end often short or mere tubercles; lower limb with 7–13 gill rakers and an indeterminate number of tubercles in front, so reduced and coalescent with one another as to be individually indistinguishable and hence their number not definitely determinable; number of gill rakers differing moderately with size, evidently some of the gill rakers changing to tubercles with growth (for these reasons, only number of gill rakers on lower limb that project appreciably above surface of arch, given in the species diagnoses, and the specimens examined divided into size groups for this purpose). Anus much nearer first anal spine than ventral base. Scales very small, partly embedded (not possible to count with any degree of precision); body almost altogether scaled; antedorsal area largely scaled to opposite preopercular margin, naked area on midback tapering backward to origin of spinous dorsal or a little short of origin; head scaleless; caudal scaled, other fins scaleless. Anterior curve in lateral line very low or hardly elevated; no scutes; accessory l.l. ending over posterior margin of head (often not discernible in large specimens of *carolinus*). First dorsal usually with 6 rather low spines: disconnected; pungent; increasing but slightly in length backward, almost subequal (the first spine often absent in *carolinus*); in young specimens spinous and soft dorsal continuous, the spines partly connected by membrane, well developed, stout, pungent, increasing gradually in length from first to seventh: with growth seventh spine becoming closely adherent to soft dorsal, the anterior 5 or 6 spines decreasing in length and becoming disconnected. Anal similar in structure and development to dorsal, the anterior two spines becoming disconnected with growth, short in large specimens. Dorsal and anal lobe moderately to excessively prolonged, depending on the species; fold at base of fins rather poorly developed; dorsal having 1–4 rays more than anal. Ventral rather short reaching about half the distance from its base to first anal spine. Pectoral slightly or hardly falcate, rather short, usually not reaching a vertical through first anal spine, sometimes reaching it. Caudal deeply forked, longer than head.

The species of this genus are recognizable by their shape; the variably deep body in combination with the characteristic truncate snout. It has a peculiar combination of characters, namely, the shape of the body and snout; normally rounded, very small scales; absence of scutes; disconnected dorsal spines; presence of well developed anterior lobes on second dorsal and anal; absence of pseudobranchiae in the larger specimens. The species of *Trachinotus* carry the tendency toward a reduction in the dentition to an extreme.

Trachinotus, Caesiomorus Lacépède (genotype *Caesiomorus baillonii* Lacépède, as designated by Jordan and Evermann, 1917, p. 61) and *Hypodis* Rafinesque (genotype *Scomber glaucus* Linnaeus as designated by Jordan and Evermann, 1917, p. 79), constitute a group of related genera. *Trachinotus* has very small embedded scales which cannot be counted with a reasonable approximation to their true number, an asymmetrical body, a characteristically broad, blunt snout and the dorsal and anal lobes well developed to very long. The genotype of *Caesiomorus* has scales that are fairly countable, a snout the shape of which more nearly approaches the ordinary, and high dorsal and anal lobes. The genotype of *Hypodis* has very small, embedded scales, a snout nearly approaching the ordinary, low dorsal and anal lobes, a comparatively slender, symmetrically shaped body and comparatively numerous gill rakers. A more comprehensive discussion of the differences between, and the similarities of these three genera, must wait until all the known species concerned are studied in constructive detail and critically compared on a world wide basis, a task which still remains to be done.

Table XI

Frequency distribution of the number of anal and pectoral rays in four species of *Trachinotus*.

	anal rays								pectoral rays				
species	16	17	18	19	20	21	22	23	16	17	18	19	20
falcatus	....	15	9	....	....	....	....	...	....	....	2	14	1
glaucus	4	23	12	....	....	....	....	....	2	5	24	5	....
marginatus ...	....	4	3	....	....	....	....	....	....	...	4	3	
carolinus	....	....	....	...	4	127	188	27	....	15	130	29	

I was able to distinguish only three species among the specimens of *Trachinotus* examined from the east coast of the United States. One species, *carolinus*, is readily distinguished by the number of dorsal and anal rays. The other two species, *falcatus* and *glaucus*, are more difficult to distinguish externally. They are fairly distinguishable by the body depth in the smaller specimens, and by the length of the dorsal and anal lobes in larger fish, as discussed under the account of *falcatus*.

A fourth species, *goodei*, the so-called permit, is supposed to occur in southern Florida, according to current accounts; but I failed to distinguish a fourth species among some hundreds of specimens examined. The bulk of the specimens examined are small, but they included also a fair number of medium-sized and large fish. The alleged *goodei* is supposed to be characterized by a combination of having a body of medium depth and the dorsal and anal lobes of medium length. In table 12 it is shown that *falcatus* decreases in relative body depth with growth, and large specimens of *falcatus* have that combination of characters which is supposed to distinguish *goodei*. Therefore, my findings cast doubt on the reality of the name *goodei* as representing a distinct species. It seems that the fish which anglers and fishermen designate "permit," usually represent large specimens of *falcatus*. Perhaps also large specimens of *carolinus* are sometimes so designated. Judged by the specimens examined, *glaucus* does not reach a large enough size to be designated "permit."

Table XII

Frequency distribution of body depth in three species of *Trachinotus*, expressed as a percentage of the standard length segregated by size, class headings referring to their mid numbers.

species	standard length in mm.	distribution													
		34	37	40	43	46	49	52	55	58	61	64	67	70	73
falcatus	13– 28	....	....	....	....	....	....	....	2	1	2	1	1		..
glaucus	14– 30	1	3	....	1	1	...	....	....	...	....	....	....	.	.
falcatus	32– 65	....	....	....	....	....	..	....	1	4	4	6	4	4	2
glaucus	33– 66	....	6	11	5	1	1	....	....	....	....	....	....		
falcatus	71– 86	....	....	....	....	....	...	....	....	....	2	1	1	2	....
glaucus	67– 90	...	...	4	2	2	1	...	....	....	....	....	.		....
falcatus	101	....	....	....	....	....	..	....	....	....	...	..	1		
glaucus	101–121	....	..	...	1	2	3	....	....	...	....	....	...		.
marginatus	108	....	....	....	....	1	....	....	....	....	...	....	....	....	
falcatus	126–133	...	...	....	....	....	....	....	....	....	1	....	2	....	1
glaucus	124–145	...	...	...	....	....	4	....	....	...	....				
marginatus	123–134	...	....	....	....	....	1	3	.					.	...
glaucus	159–167	....	....	....	...	....	....	2	2	.	.			..	..
marginatus	168	...	....	....	....	....	1	....	....	....	.			.	.
falcatus	172–251	....	....	...	..	....	..	....	1	2	2	1			..
glaucus	172–236	....	....	....	....	....	3	8	3	.				...	..
marginatus	225	....	....	...	....	....	....	1	....				..	....	..
falcatus	324–415	....	....	...	....	....	...	1	2	2			.	.	....
falcatus	574	....	....	....	....	....	1		.	..	....	..	....	....	....

The apparent existing misapprehension regarding the western Atlantic species of *Trachinotus* involves also a curious confusion of common and scientific names. In current accounts, the "permit" is generally treated under the name of *T. goodei*. However, as stated, the name "permit" apparently refers, partly or wholly, to large specimens of *falcatus;* while the type on which the name *goodei* is based, is evidently a small specimen of *glaucus* as noted under its account, and the name *goodei* must be entered in the synonymy of *glaucus*.

Trachinotus falcatus (Linnaeus)

Round pompano; permit (large fish),—Plate 3, fig. b; plate 4, fig.b

Labrus falcatus Linnaeus, Syst. Nat., p. 284, 1758 (America)

Chaetodon rhomboides Bloch, Ichthyologie ou Histoire Naturelle des Poissons, pt. 6, p. 75, pl. 209, 1788 (America, from a drawing by Plumier)

Trachynotus rhomboides Meek and Goss, Proc. Acad. Nat. Sci. Philadelphia 1884: 124 (Woods Hole to Brazil)

Trachinotus falcatus Jordan and Evermann, Bull. U. S. Nat. Mus. 17(1): 911, pl. 146, fig. 396, 1896 (West Indies: Cape Cod to Brazil).—Nichols, Bull. Amer. Mus. Nat. Hist. 31: 186. 1912 (Havana market).—Meek and Hildebrand. Publ. Field Mus. Nat. Hist. Chicago (zool. ser.) 15(2): 378, pl. 33 (young), 1925 (Atlantic coast of Panama).—Nichols and Breder, Zoologica 9: 116, fig. 157, 1927 (Woods Hole, Mass.; Orient, N.Y.).—Hildebrand and Schroeder, Bull. U. S. Bur. Fish. 43(1): 228, figs. 133–134, 1928 (Chesapeake Bay).—Gunter, Copeia 1935(1): 40 (East Bay, Louisiana).—Fowler, Bull. Amer. Mus. Nat. Hist. 70(2): 721, fig. 322

(young). 1936 ("Tropical Atlantic").—Baughman, Trans. Texas Acad. Sci. 24: 23. 1941 (Rockport, Texas).—Longley and Hildebrand, Carnegie Inst. Washington Publ. 535: 80, 1941 (Tortugas, Florida).—Gunter and Knapp, Texas Jour. Sci. 3: 136, 1951 (Mustang Island, Texas)

D VI; I 18–20. A II; I 17–18. P 18–20. GR 9–11.

Gill rakers on lower limb 12–13 in 9 specimens 30 to 60 mm.; 9–11 in 10 specimens 85–495 mm. Body notably deep in small specimens, with growth the depth decreasing in proportion (see table 12). Teeth on jaws, vomer and palatines disappearing in medium sized specimens, and on tongue in large specimens. Prolonged dorsal lobe usually reaching approximately to a vertical through caudal base in the larger specimens, varying moderately both ways; the anal lobe considerably shorter than dorsal; dorsal lobe 38–49 in specimens 172–251 mm., the lobes comparatively shorter in the smaller and in very large specimens.

TABLE XIII

Frequency distribution of the length of the dorsal lobe in four species of *Trachinotus*, expressed as a percentage of the standard length, segregated into size groups, class headings referring to their mid numbers.

	standard length in mm.											distribution												
		18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	63	66	69	72	75	78	81	84
	13– 28	1	4	1																				
	14– 30		1	4		1						....												
	32– 65		2	10	7	2	2																	
	33– 66	....	3	14	6	1																		
s	50– 64	....	1	1																				
	71– 86			1		5																		
	67– 90	....	....	....	2	1	1	3	2															
s	67– 85		1	3																				
	101	....	....	....	....	....	....	....	....	1														
	101–121	....	....	....	....	....	....	1	2	2	1													
tus	108	....	....	....	....	1																		
s	109–115	....	....	2	1	....	....	....	....	....														
	126 -133							1		3														
	124–145	....	....	....	....	....	....	....	....	....	....	....	1	2	1									
tus	123 134				1	3																		
s	119–146	....	....	3	3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....			
	159-167										1			1							2			
tus	168	....	....	....	....	....	....	1	....	....	....													
	172–251	....	....	....	....	....	....	....	1	2	....	1												
	172–225	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	3	1	3		2	
tus	225	....	....	....	....	....	....	....	1															
s	180–236	....	....	2	2	....	....	....	....	....	....													
	330 415								2	1	1													
s	322–428	....	1	2	....																			

Silvery or golden, darker above, lighter below; elongate rays of dorsal and anal and broad marginal upper and lower areas on caudal dusky to nearly black; no cross bands or other distinctive marks. Small specimens are sometimes rather uniformly dark or dusky.

Gulf specimens examined from Tampa (market), Clearwater and Cedar Keys, Florida: Aransas Pass, Corpus Christi Pass, and Corpus Christi Bay, Texas. On the Atlantic coast specimens examined from Woods Hole, Massachusetts; Long Island, New York; Beesleys Point, New Jersey; Ocean View and Old Point Comfort, Virginia; Lake Worth, Marquesas Key, Key West and Tortugas, Florida. Also, Hog Island, Bahamas; Cuba; Jamaica; Haiti; Dominican Republic; Puerto Rico; Colon and Toro Point, Panama; Sabanilla, Colombia; Lake Maracaibo, Venezuela; Porto Seguro, Brazil. The largest specimen is 790 mm. (31″) obtained in the New York Market. The largest Gulf specimen is 184 mm. (7″) from Corpus Christi Bay. Specimens examined from Massachusetts to Virginia are all small, the largest 98 mm.

A mounted specimen on exhibition at the National Museum, about 3 feet long, labeled "permit," looked at through the glass front of the exhibition case, appears to belong to this species. The body seems to be stouter than that of the specimens examined but this is probably an effect produced during the process of mounting.

Table XIV

Frequency distribution of the length of the anal lobe in four species of *Trachinotus*, expressed as a percentage of the standard length, segregated into size groups, class headings referring to their mid numbers.

species	standard length in mm.	distribution																	
		19	22	25	28	31	34	37	40	43	46	49	52	55	58	61	64	67	70
falcatus	13–28	1	3	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
glaucus	14–30	1	4	1															
falcatus	32–65	2	18	2	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....
glaucus	33–66	4	13	7															
carolinus	50–64	....	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
falcatus	71–86	....	1	5															
glaucus	67–90	....	1	3	2	2	1												
carolinus	67–85	1	3																
falcatus	101	....	....	....	....	1													
glaucus	102–121	....	....	....	....	1	1	2	1										
marginatus ..	108	....	....	1															
carolinus	109–115	....	3																
falcatus	126–133	....	....	....	2	1	1												
glaucus	124–145	....	....	....	....	....	....	....	....	2	1	1	....	....	....	....	....	....	....
marginatus ..	123–134	....	1	2	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....
carolinus	119–146	....	5	1	....	....	....	....	....	....	....	....	....	....	....	....	....		
glaucus	159–167	....	....	....	....	....	....	....	....	1	....	1	....	....	....	1	1		
marginatus ..	168	....	....	....	1														
falcatus	172–251	....	....	....	2	3	....	....	....	....	....	....	....	....	....	....	....	....	
glaucus	172–225	....	....	....	....	....	....	....	....	....	....	....	1	....	2	2	2	....	2
marginatus ..	225	....	....	....	1														
carolinus	180–236	1	1	2															
falcatus	330–574	....	2	1	2														
carolinus	322-332	1	1																

This species has the same fin ray count as, and is near to *glaucus*. The bulk of the smaller specimens of *falcatus*, those less than 150 mm. in standard length, are usually distinguished on sight by their notably deep body; although the proper placement of occasional peripheral small fish by body depth is attended with some uncertainty. The proper distinction of the larger specimens is even more difficult. In *falcatus* the body becomes relatively more slender in the larger specimens, in those over 175 mm.; while in *glaucus* the relative depth increases steadily with growth. Consequently, the larger specimens of the two species closely approach in relative depth. However, in the larger specimens of *glaucus* the dorsal and anal lobes become greatly elongated and the two species are then fairly separable on that basis. The divergence between the two species in the length of the anal lobe is more pronounced than that of the dorsal lobe. In *glaucus* the anal lobe increases with growth nearly as much as the dorsal lobe while in *falcatus* it increases at a slower rate. The change of measurements with size and the species differences are shown in tables 12 to 14.

The absence of dusky cross bars in *falcatus* and their presence in *glaucus* is of considerable help in distinguishing the two species. But the bars are absent in small preserved specimens of *glaucus* as well, and sometimes also in the larger preserved specimens. The distinguishing characters between this species and *marginatus* and *carolinus* are indicated under the accounts of those species.

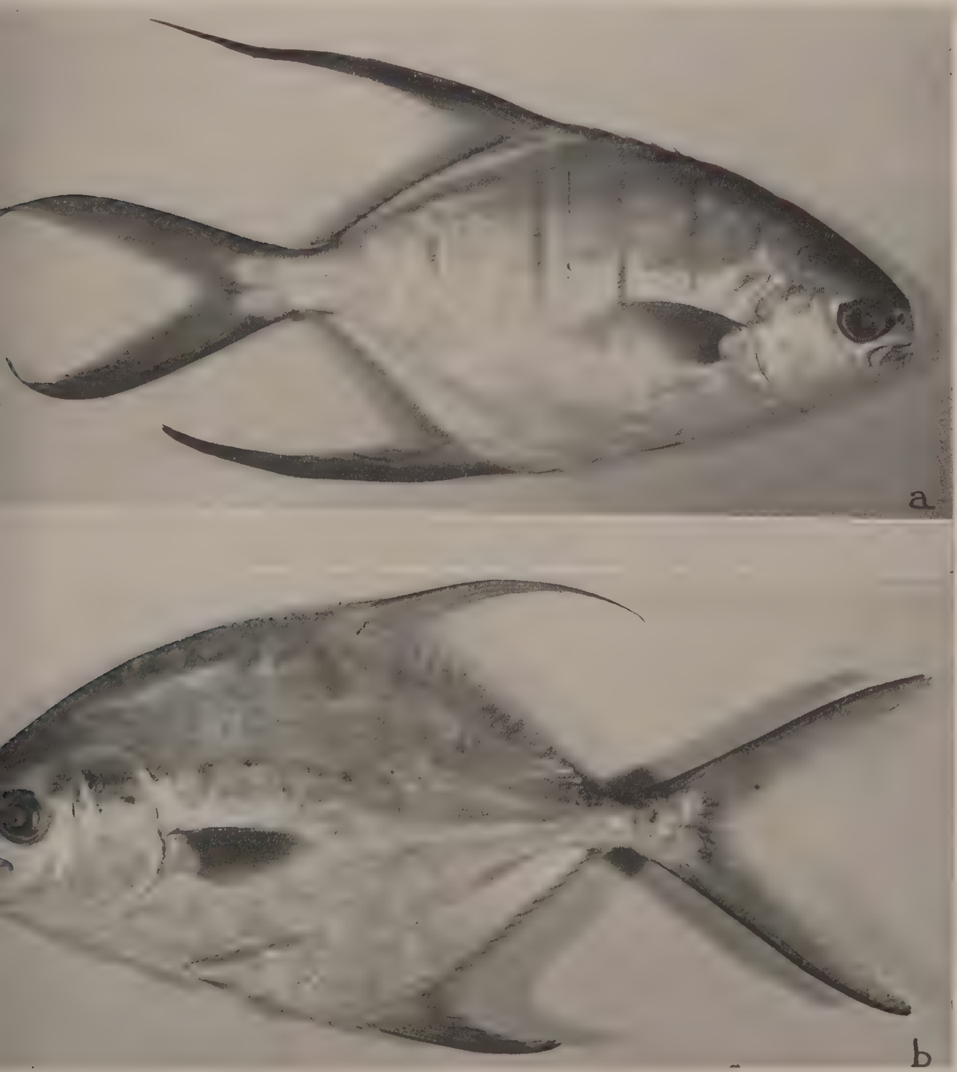


Plate 3

Fig. a. *Trachinotus glaucus*, 292 mm Nassau, Bahamas. USNM 5314.

Fig. b. *Trachinotus falcatus*, 301 mm Florida. USNM 26585. In large specimens the body becomes comparatively not as deep and the dorsal and anal lobe relatively shorter. The species commonly called permit apparently refers to such large specimens of *falcatus*.

Trachinotus glaucus (Bloch)

Longfin pompano, Plate 3, fig. a; Plate 4, fig. a

Chaetodon glaucus Bloch, Ichthyologie ou Histoire Naturelle des Poissons. pt. 6, p. 76, pl. 210, 1788 (America, on a drawing by Plumier)

Trachinotus glaucus Jordan and Evermann. Bull. U. S. Nat. Mus. 47(1): 940, pl. 146, fig. 395, 1896 ("Tropical America, from Virginia to the Caribbean Sea").—Meek and Hildebrand, Publ. Field Mus. Nat. Hist. Chicago (zool. ser.) 15(2): 382, pl. 36, fig. 1 (young), 1925 (Atlantic coast of Panama).—Fowler, Bull. Amer. Mus. Nat. Hist. 70(2): 719, fig. 321, 1936 (Costa Rica; Santo Domingo)

Trachinotus goodei Jordan and Evermann, Bull. U. S. Nat. Mus. 47(1): 943, 1896 (The description of the holotype, "a small specimen from Key West," agrees with the species here treated.)

Trachinotus palometa Regan. Ann. Mag. Nat. Hist. (7) 12:349, 1903 (*palometa* substituted for *glaucus* after unacceptably placing *Scomber glaucus* Linnaeus in *Trachinotus* resulted in [Chaetodon] *Trachinotus glaucus* (Bloch) becoming a homonym).—Longley and Hildebrand, Carnegie Inst. Washington Publ. 535:81, 1941 (Tortugas, Fla.).—Gunter, Publ. Inst. Mar. Sci. Univ. Texas 1(1): 60, 1945 (Texas).—Baughman, Texas Jour. Sci. 2:246, 1950 (Texas).—Gunter and Knapp, ibid., vol. 3, p. 136, 1951 (Mustang Island, Texas)

D VI; I 19–20. A II; I 16–18. P 16–19. GR 8–11.

Gill rakers on lower limb 10–12 in 9 specimens 33–70 mm., 8–11 in 16 specimens 85–335 mm. Body moderately deep. with growth the depth increasing in proportion (see table 12). Teeth in jaws, on vomer and palatines persistent with growth but becoming reduced in extent on roof of mouth; absent on tongue. Prolonged dorsal and anal lobe reaching much beyond a vertical through caudal base in the larger

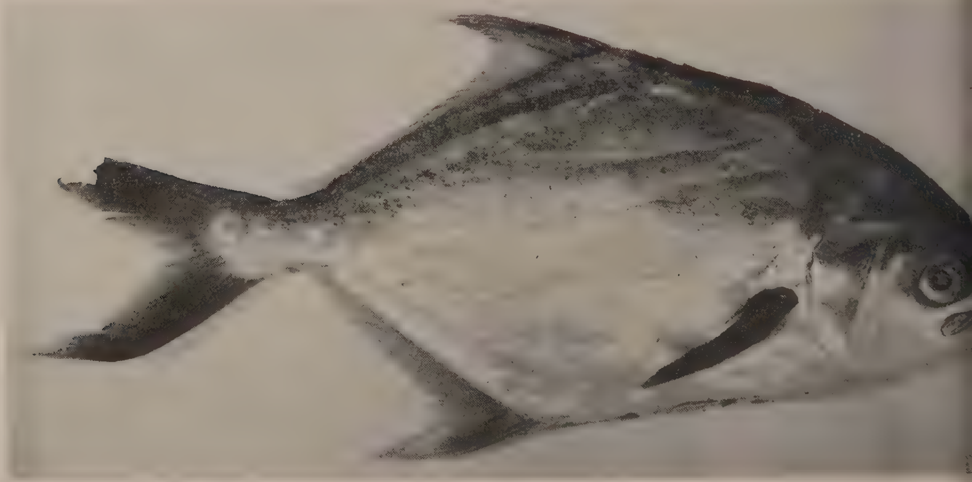


PLATE 3—(Continued)

Fig. c. *Trachinotus carolinus*, 322 mm Rio de Janeiro, Brazil, USNM 87792. Specimen figured having pectoral fin twisted and inner surface exposed.

specimens, anal lobe subequal to dorsal or moderately shorter; dorsal lobe 61–84 in specimens 172–225 mm. in standard length: the lobes comparatively shorter in the smaller specimens.

Ground color silvery or golden; with 4 brownish cross bars on upper part of body; the first a little in front of first dorsal spine; the fourth nearly under middle of soft dorsal, more widely spaced and shorter than anterior three bars, sometimes very short or absent in preserved specimens; the first three bars extending over the greater part of the distance between lateral line and midback and continued for a short distance

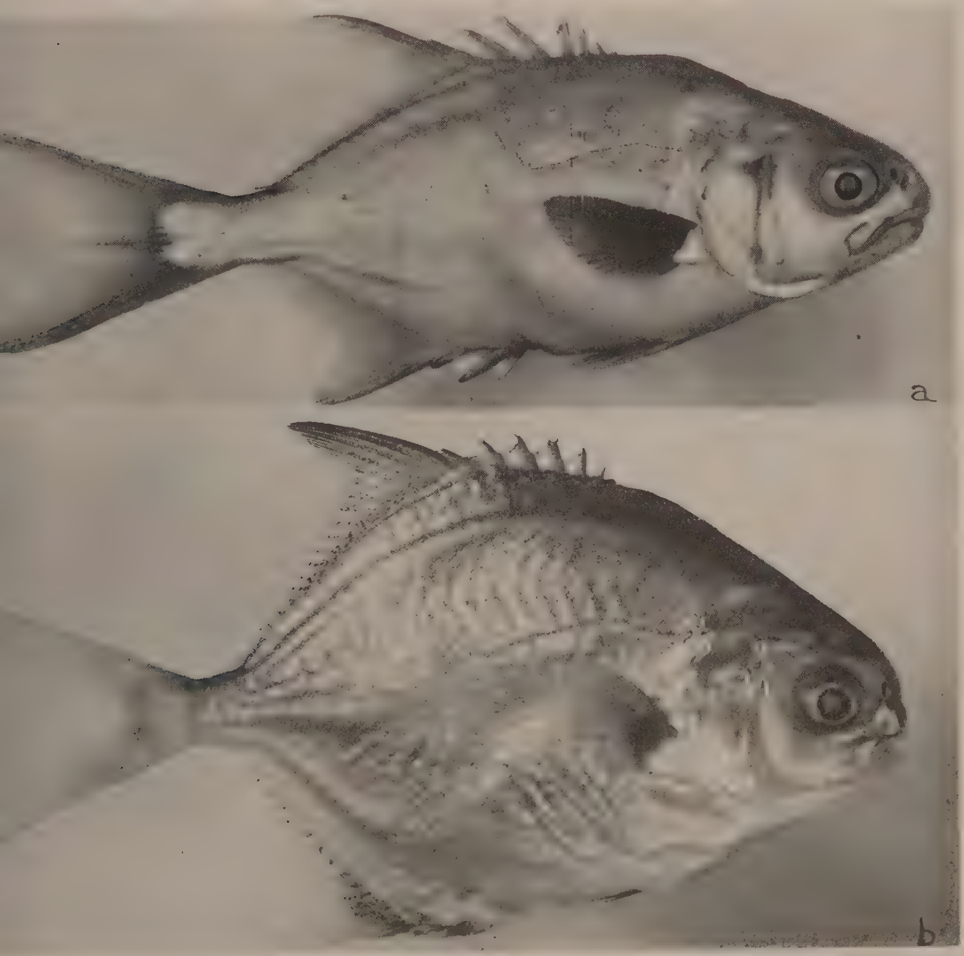


PLATE 4

Small specimens of the three species of *Trachinotus* on the east coast of the United States. The fins relatively short in all three species.

Fig. a. *Trachinotus glaucus*, 87 mm Tortugas, Fla. USNM 143952.

Fig. b. *Trachinotus falcatus*, 81 mm Old Point Comfort, Va. USNM 143941. Body depth very striking, relatively deeper than in adult.

below l.l.; caudal peduncle often with one or two brownish spots at lateral line, one behind the other; elongate dorsal and anal rays and a broad outer area on caudal lobes dark to nearly black. In small preserved specimens the cross bars are not evident and they are sometimes faint or hardly perceptible in the larger specimens.

Gulf specimens examined from Pensacola, Florida; Aransas Pass, Texas; Louisiana. On the Atlantic coast specimens examined from Woods Hole, Marthas Vineyard, Massachusetts; Beaufort, North Carolina; St. Augustine, Marquesas Key, Key West and Tortugas, Florida. Also from Nassau, Bahamas; Cuba; Puerto Rico; Old Providence Island; Cozumel Island, Mexico; Honduras; Colon, Panama; Sabanilla, Colombia; Gulf of Venezuela; Rio de Janeiro and Porto Inhauma, Brazil. The largest specimen is 335 mm. (13″) from Panama. The largest Gulf specimen is 300 mm. (12″) from Pensacola.

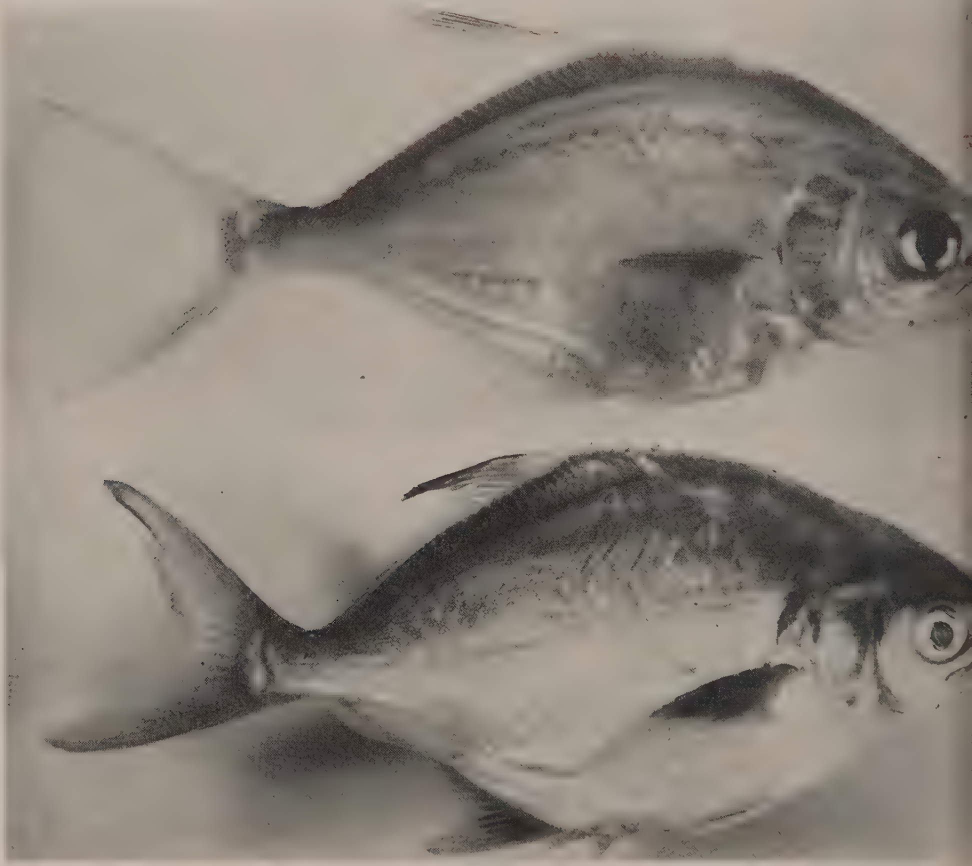


PLATE 4—(Continued)

Fig. c. *Trachinotus carolinus*, 89 mm Galveston, Texas. USNM 118663.

Fig. d. *Trachinotus carolinus*, 130 mm, 101 mm in standard length. Grand Isle, La. USNM 118968. A size at which about maximum depth is attained. Such deep specimens sometimes designated *T. argenteus*.

The larger specimens of this species are usually distinguishable at a glance by the combination of having the dorsal and anal lobe much prolonged, a body of medium depth and comparatively long, dusky cross bars. It is further compared with *marginatus, falcatus* and *carolinus* under the accounts of those species.

Nomenclature.—Regan (cited in synonymy) substitutes the name *palometa* for this species, on the assumption that *Scomber glaucus* Linnaeus (1758) belongs to *Trachinotus*, which causes the *T. glaucus* of Bloch (1788) to become a homonym. However, Regan's generic placement of *S. glaucus* L., is unacceptable as it differs generically from *Scomber falcatus* Linnaeus which is the genotype of *Trachinotus*. (Linnaeus' species has been designated as the genotype of *Hypodis* Rafinesque by Jordan and Evermann, 1917, p. 79.) Besides, this species has a synonym, *goodei*, as indicated in the above synonymy, which antedates *palometa* of Regan.

Trachinotus marginatus Cuvier and Valenciennes

Plate 5, fig. a

Trachinotus marginatus Cuvier and Valenciennes, Hist. Nat. Poiss. 8: 411. 1831 (sent in from Montevideo)

D VI; I 19–21. A II; I 17–18. P 18–19. GR 11–12.

Gill rakers on lower limb 10–12 in 7 specimens 148–320 mm. Body moderately deep (see table 12). Teeth in jaws on vomer and palatines in specimens 148–230 mm., in reduced number in jaws and very few or absent on palatines and vomer in one specimen 320 mm.; absent on tongue in all. Dorsal and anal lobes falling short of a vertical through caudal base; dorsal lobe 38 in a specimen 225 mm. in standard length.

Ground color golden or silvery upper part brownish, rather dark in largest specimen; with a row of 4 or 5, transversely oblong dark spots or short bars at lateral line, the row beginning approximately under middle of spinous dorsal and ending a little in front of end of soft dorsal; larger part of spots extending moderately above lateral line, their lower ends touching l.l. or extending a little below; the spots well marked in the largest specimen, rather faint or hardly perceptible in smaller fish; pectoral, and dorsal, anal and caudal lobes dark to nearly black.

Specimens examined: Rio de Janeiro (76320), Montevideo, Uruguay (77311), Uruguay (86713, 87728). Total examined 7 specimens, 148–320 mm. The four lots of specimens sporadically obtained by various collectors would seem to indicate that the species is not uncommon on the coast of South America.

This species nearly agrees with *falcatus* and *glaucus* and differs from *carolinus* in the number of dorsal and anal rays. It differs from *falcatus* in having transversely elongate spots or short bars and in not having the body as deep as in that species. In the depth of the body it nearly agrees with *glaucus* and differs from it in having the dorsal and anal lobes and the cross markings shorter.

Trachinotus carolinus (Linnaeus)

Common pompano, Plate 3, fig. c; Plate 4, figs. c and d

Gasterosteus carolinus Linnaeus, Syst. Nat., ed. 12, t. 1, p. 490, 1766 (Carolina)

Trachinotus carolinus Jordan and Evermann, Bull. U. S. Nat. Mus. 47(1): 944, pl. 147, fig. 398, 1896 ("South Atlantic and Gulf coasts of United States, ranging north to Cape Cod . . . rare or accidental in the West Indies and in Brazil").—Nichols and Breder, Zoologica 9:117, fig. 160, 1927 (Woods Hole, Mass.; New York).—Hildebrand and Schroeder, Bull. U. S. Bur. Fish. 43(1): 229, fig. 135. 1928 (Chesapeake Bay).—Gunter. La. Conserva. Rev. 5(4): 22, 1936 (Louisiana). —Longley and Hildebrand, Carnegie Inst. Washington Publ. 535: 81, 1941 (Tortugas, Fla.).—Baughman, Trans. Texas Acad. Sci. 24:23, 1941 (Texas).—Gunter. Publ. Inst. Mar. Sci. Univ. Texas 1(1): 59, 1945 (Texas; life history notes).—Baughman, Texas Jour. Sci. 2: 246, 1950 (Texas)

Trachinotus argenteus Cuvier and Valenciennes, Hist. Nat. Poiss. 8:413, 1831 (sent in from New York and Rio de Janeiro).—Smith, Bull. U. S. Fish. Comm. 17:98. 1898 (a specimen from Woods Hole identified by Baird as argenteus).—Bean. Nineteenth Rep. Comm. Fish. New York, p. 257, fig. 13, 1890 (Blue Point Cove. Long Island).—Jordan and Evermann, Bull. U. S. Nat. Mus. 47(1): 944, 1896 ("Atlantic Coast").—Nichols and Breder, Zoologica 9: 116, fig. 159, 1927 (Woods Hole).—Nichols, Marine Life 1(8): 41, 1950 (off Long Island)

D V—VI; I 23–27. A II; I 20–23. P 17–19. GR 7–11.

Gill rakers on lower limb 9–11 in 4 specimens 65–85 mm., 7–10 in 17 specimens 90–570 mm. Body moderately deep (for a *Trachinotus*), changing with growth (see table 15). Teeth present in jaws; absent on vomer, palatines and tongue; with growth disappearing in jaws. Dorsal and caudal lobe moderate, subequal, reaching to about middle of dorsal and anal base: dorsal lobe 25–27 in specimens 180–236 mm. First dorsal spines often 5 (see table 10).

Silvery, with a grayish tinge on upper half, lighter below; fins dusky in the larger specimens, usually almost uniformly so; no cross bands.

Gulf specimens examined from Clearwater Beach, Apalachicola Bay, Sand Island. St. Vincent Island, Cape San Blas and Pensacola, Florida; Chandeleur Islands. Grande Terre, Grande Isle, Caminada Pass and Isle Derniere, Louisiana; Galveston. Matagorda Bay, Pass Cavallo, St. Joseph Island. Aransas Pass. Corpus Christi Bay and Corpus Christi Pass, Texas. On the Atlantic coast of the United states specimens examined range from Woods Hole, Massachusetts to Key West, Florida. Specimens also examined from Merida, Yucatan, Mexico; Puerto Rico: Fort Sherman, Panama: Sabanilla, Colombia: Gulf of Venezuela: Pernambuco, Santos, Rio de Janeiro and Porto Inhauma, Brazil. The largest specimen, 570 mm. (25″) is from New York (most probably obtained in market). The largest Gulf fish is 440 mm. (17″) from Pensacola.

This species is readily separable from *falcatus*, *glaucus* and *marginatus* by the number of soft dorsal and anal rays, there being no intergradation with the other three species in these counts in *carolinus*. It differs further from *marginatus* and *glaucus* in not having cross bands or elongate spots, and from *falcatus* in not having the body as deep. In its comparatively low dorsal and anal lobes it is nearest *marginatus*.

Ontogeny.—This species undergoes considerable change with growth in its body depth, as shown in table 15. The relative depth first increases and, on the whole. reaches its maximum in fish between 110–130 mm. in standard length. After that size is attained the relative depth decreases. At a given size range individual variants may be either advanced or retarded in the development of body depth. Table 15 includes measurements of specimens from the entire geographic range of the species and no account was taken of any possible population differences in body depth, or differences in its tempo of change with growth by locality.

TABLE XV

Frequency distribution of the body depth of *Trachinotus carolinus*, expressed as a percentage of the standard length, segregated into size groups.

											distribution												
	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
		1	3	6	2																		
	1	....	....	2	2	4	8	3															
				1	4	6	2	3	2	....	....												
				1	1	2	4	5	5	4	1												
					2	3	9	7	10	15	5	5	4	1									
	....	....	....			1	4	2	9	1	11	10	4	5			1					....	
	....	....	....	....	....	....	2	5	5	4	8	14	11	4	4	3	1	....	....				
											2	2	3	5	3	5	4	3	2				1
	....	....	....	....	....	....	....	....	....	....			2	4	6	6	2	3	1	1	2	1	
	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3	2	2	2	2	3	....	1	1
	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2	2	4	2	1
	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	1	4	5	1	1	1	2	
									1	1	1		1	1						....	....		

Small specimens are rather symmetrically shaped, and the greatest body depth is at about the middle of the belly. However, with growth the fish becomes somewhat asymmetrical, the apex of the ventral outline which coincides with the anal origin, is a little more posterior to the apex of the dorsal profile which coincides with the dorsal origin. In the latter specimens the depth was measured on the greatest vertical which is at the dorsal origin. Therefore, the depth in the smaller specimens was also measured on a vertical at the same point, although it does not represent the greatest depth in such specimens. The table shows the precise change with growth in the depth at the point measured, which is somewhat less than the greatest depth in the small specimens.

The number of dorsal spines in *carolinus* varies considerably with the individual. This variability is based on the first spine. It is normally short, varying to a slight stump hidden under the skin; and often it is absent altogether, in 51 specimens out of 346 examined for this character, as shown in table 10. This variability in the first spine is shown by small as well as large specimens. In addition to this individual variation, there appears to be a growth change also, as shown by

Standard length			Number of spines	
			6	7
class	12– 50	frequency	13	166
class	51–274	frequency	34	128
class	285–428	frequency	4	1

the accompanying tabulation. All the spines become shorter with growth, and it appears that in large fish the first spine usually disappears.

Populations.—Table 16 shows considerable differences by local population in the frequency distribution of the dorsal and anal rays and dorsal spines. The distribution is virtually the same in the samples ranging from Buzzards Bay to Chesapeake Bay. The population of North Carolina averages higher fin ray counts. The highest average fin ray counts obtains in the population from northwestern Florida; while the Louisiana and Texas populations differ only slightly from those at the northern part of the geographic range of the species. The South American populations, especially that of Venezuela, are characterized by averaging low counts. The samples examined from Colombia and Venezuela constantly have 7 dorsal spines.

TABLE XVI

Population differences in the frequency distribution of the number of dorsal and anal rays and dorsal spines in *Trachinotus carolinus*.

locality	dorsal spines		dorsal rays					anal rays			
	6	7	23	24	25	26	27	20	21	22	23
Buzzards Bay, Mass.	7	20	2	19	16	....	....	1	8	17	1
Noank, Conn. to Longport, N. J.	8	21	2	17	9	..	...	1	11	16	1
Chesapeake Bay, at its mouth	6	21	3	15	9	....	....	....	11	15	1
Beaufort, N. C.	10	45	2	29	18	6	....	....	17	31	8
Apalachicola to Pensacola, Fla.	6	44	....	13	30	5	1	....	6	32	12
Chandeleur Ids. to Isle Derniere, La.	5	43	5	25	18	....	....	1	21	26	..
Galveston to Aransas Pass, Texas	5	43	7	29	12	. .	....	....	22	23	3
Sabanilla, Colombia	....	34	7	23	2	1	....	....	18	16	
Gulf of Venezuela	....	9	7	2	....	....	....	....	6	2	.
Brazil	1	6	1	4	2	....	....	1	2	2	1

Data presented by Gunter (Pub. Inst. Marine Sci., vol. 1, no. 1, 1945) indicate that *T. carolinus* is by far the most abundant pompano on the Gulf Coast. He called attention to the great numbers of young along the Gulf beaches in summer.

Synonymy.—A species of *Trachinotus* closely related to *carolinus*, has been recorded by some authors from eastern United States, under the name of *argenteus*, as noted in the above synonymy. The only character hitherto advanced for distinguishing the supposed *argenteus* from the common *carolinus*, is its surmised greater depth of body. However, a determination of the growth change in the body depth of *carolinus* and its intraspecific variability at any given narrow size range, as is shown in table 15, puts this question in its proper perspective. At any given size, *carolinus* shows considerable variability in the body depth; while the maximum depth attained by *carolinus*, in the 110–130 mm. size group, is somewhat greater than the depth of the alleged *argenteus*, given by those authors who claim that it constitutes a distinct species. Certainly, no distinct species can be established on the basis of the given depth difference alone in the absence of corroborating characters. It is evident that *argenteus* should be erased from the list, at least as far as it relates to eastern United States.

One of the specimens previously recorded as *argenteus*, the one recorded by Bean (1890) from Long Island (36036), has been reexamined. It has an unusually deep body for its size. It is the extreme specimen in the 66–80 mm. category in table 15. The appearance of the specimen is such that when compared with the more slender specimens in its size group, one might tentatively conclude that it belongs to a different species. However, a comparison of its depth measurement with the frequency distribution of *carolinus*, in its and adjacent size group, the striking depth of this specimen loses its significance as a specific character. A study of table 15, suggests two possible explanations for the unusual depth, at its size. First, it might be a stunted specimen of approximately the same age as the specimens in category 110

130 mm., and its deep body is in accordance with its age. Second, it might be that it is a precocious specimen which developed the body form of the larger and older fish.

SELAR Bleeker

Selar Bleeker Nat. Tijdschr. Ned. Indie 1:343. 352, 353 and 359 362. 1850 (genotype *Selar boops* (Cuvier and Valenciennes) by later designation). Jordan and Evermann, Bull. U. S. Nat. Mus. 47(1): 916, 1896 (*Caranx boops* Cuvier and Valenciennes designated as genotype).—Fowler, Proc. Acad. Nat. Sci. Philadelphia 1918:14 (*Caranx boops* Cuvier and Valenciennes designated genotype)

Trachurops Gill, Proc. Acad. Nat. Sci. Philadelphia, 1862:238 (genotype *Caranx plumieri* (Bloch) = *Scomber plumieri* Bloch = *Scomber crumenophthalmus* Bloch by monotypy)

Selar is nearest *Decapterus* and *Trachurus.* It differs from *Decapterus* in that the last dorsal and anal rays, although notably thickened, are not detached to form separate finlets. It differs from *Trachurus* in having two well developed papillae on the shoulder girdle and in not having the anterior scales in the lateral line greatly expanded transversely.

Nomenclature.—Nichols (1942) who claims that *boops* cannot be the genotype of *Selar*, because it is not one of the originally included species, evidently overlooked one of the pages in Bleeker's paper establishing this genus. On page 343 in the work cited in the above synonymy, where the name *Selar* is used for the first time, Bleeker gives a bare list of 12 species combined with this generic name. One of the included species is given as "*Selar boops* Blkr. = *Caranx boops* C.V." This species was subsequently designated as the genotype of *Selar* twice, once by Jordan and Evermann and later by Fowler as noted above. According to Articles 25 and 30 of the international code. and Opinion 1 of the international commission, *Selar* is a valid genus with *Caranx boops* Cuvier and Valenciennes as its genotype.

On page 352 Bleeker gives a definition of *Selar* without mentioning any species. On page 353 he gives a brief discussion of the genus and mentions three species, *plumieri, analis* and *djeddaba.* On pages 359–362 he gives descriptions of five species, *macrurus, hasseltii, kuhlii, brevis* and *malam.* All this is really beside the point. These facts are mentioned here, because Nichols depended on the record in these later pages to draw a seemingly correct conclusion regarding the genotype of *Selar*, but one which is in reality untenable.

For the common species *crumenophthalmus*, American authors have widely used the generic name *Trachurops* for a long time. From the viewpoint of American authors then it would seem desirable to preserve this well established name. However, for the extra-American species of the same genus, as used by other authors especially, the name *Trachurops* did not command any extensive usage, and in this instance it seems best to follow the Rules.

Selar crumenophthalmus (Bloch)

Bigeye scad

Scomber crumenophthalmus Bloch, Ichthyologie ou Histoire Naturelle des Poissons 10:65, pl. 343, 1797 (Guinea)

Scomber plumieri Bloch, ibid. p. 67, pl. 344 (Antilles)

Caranx crumenophthalmus Gunther. Cat. Fish. Brit. Mus. 2:429, 1869 (Atlantic and Pacific localities)

Trachurops crumenophthalmus Gill, Proc. Acad. Nat. Sci. Philadelphia 1862: 432 (Beesley's Point, New Jersey).—Jordan and Evermann, Bull. U. S. Nat. Mus. 47(1): 911, pl. 141, fig. 385, 1896 ("Both coasts of tropical America, occasionally north to Cape Cod . . .").—Nichols, Bull. Amer. Mus. Nat. Hist. 31:185, 1912 (Cuba).—Nichols, Copeia 1920: 96 (Long Island).—Nichols and Breder, Zoologica 9: 111, fig. 149, 1926 (Woods Hole, Mass.; Orient, N.Y.).—Nichols, Amer. Mus. Novit. 815:1, 1935 (Pacific localities).—Longley and Hildebrand, Carnegie Inst. Washington Publ. 535: 76, 1941 (Tortugas, Florida).—Fowler, Monog. Ac. Nat. Sci. Philadelphia 6: 149 and passim, 1944 (various Atlantic and Pacific localities scattered through the pages)

Selar crumenophthalmus Fowler, Proc. Acad. Nat. Sci. Philadelphia 1918: 15 (Philippine Islands).—Hildebrand and Schroeder, Bull. U. S. Bur. Fish. 43(1): 217, fig. 126, 1928 (Chesapeake Bay).—Fowler, Bull. Amer. Mus. Nat. Hist. 70(2): 689, fig. 309, 1936 (United States; West Indies; Cape Verde Islands)

D VIII; I 24–26. A II; I 21–23. P 20–22. Scutes 30–41. GR 27–30.

Dorsal rays usually 25 (10) or 26 (8), sometimes 24 (1). Anal rays modally 22 (14), often 23 (3) or 21 (2). Dorsal spines constant (19). Pectoral rays modally 21 (17), sometimes 20 (1) or 22 (1). Gill rakers long, 9–11+27–30, sometimes one tubercle at anterior end of lower limb; total number of gill rakers and tubercles on both limbs 37–41. Body moderately slender, rather spindle shaped, depth 25–29 in 11 specimens 65–270 mm.; caudal peduncle moderately slender. Snout moderate, subequals eye, obtuse. Eye notably large. Adipose eyelid very well developed, covering greater part of eye. Maxillary of moderate width, ending under anterior margin of pupil; supplemental maxillary rather narrow. Mouth medium, well inclined, subsuperior, lower jaw projecting. Teeth small, in one row in lower jaw, two rows in upper jaw; in a narrow band on head of vomer and on palatines; a narrow, short forward extension on head of vomer, none on shaft; a rather wide or medium band on tongue. Shoulder girdle with two widely separated, coarse papillae, the upper one but slightly rising, the lower one conspicuously well developed. Anus placed at a moderate distance from first anal spine. Scales small; antedorsal area and interorbital scaled nearly to opposite anterior margin of eye; cheek, opercle and interopercle largely scaled; fins more or less scaled. Anterior curve in lateral line very low, continued very gradually into posterior straight part; scales in posterior part scute-like, 30–41; scales in anterior part of 1.1. normally rounded, not scute-like, 50–58; total number of scales in 1.1. 84–93; accessory 1.1. ending under beginning or middle of first dorsal. First dorsal rather high, the spines connected by membrane, the anterior spines rather flexible; first spine comparatively long and thin, about one half the third and longest; fourth spine shorter than or subequal to third; thence rapidly decreasing to last. The two disconnected anal spines well developed. Dorsal and anal lobe moderately elevated; fold at their base moderate; dorsal having 2–4 more rays than anal. Ventral moderately long, reaching more than half the distance from its base to soft anal origin; its outer angle under lower pectoral angle or slightly behind. Pectoral moderately long about reaching over beginning of soft anal in large specimens. Caudal rather short, shorter than head, well lunate.

Silvery or golden, almost uniformly colored or upper part dark; a marginal spot on opercle rather faint or absent; no distinctive color marks.

Only 2 Gulf specimens, 115-185 mm. examined from off Isle Dernière and Grand Isle, La. On the Atlantic coast of the United States specimens examined range from Woods Hole, Mass. to Norfolk, Va., and from Tortugas, Fla. Also, from Bermuda; Nassau, Bahamas; Cuba; Cozumel Island, Mexico; Honduras; Puerto Rico; St. Thomas Island; Barbados; Old Providence Island; Curacao; Porto Bello, Panama; Bahia, Brazil. The largest specimen is 270 mm. (11″) from Cuba.

As compared with the Gulf fishes, this species is nearest structurally and in general appearance to *Decapterus punctatus* and *Trachurus lathami*. The main structural differences between the species are discussed under the genus. This species has a notably large eye which is largely covered by the well developed adipose eyelid, except for a moderate open slit at the middle. This feature in combination with the other structural characters discussed above. makes it easy to identify and distinguish it from the other Gulf species.

DECAPTERUS Bleeker

Decapterus Bleeker, Nat. Tijdschr. Nederl. Ind. Batavia 1: 342, 352 and 358, 1850 (two species included, *kurra* and *macrosoma*; genotype *Caranx kurra* Cuvier and Valenciennes by later designation).—Jordan and Gilbert, Bull. U. S. Nat. Mus. 16: 432, 1882 (*Caranx kurra* C. and V. designated as genotype)

Decapterus is near to *Selar*, nearly agreeing with it in most generic characters, including the presence of two papillae on the shoulder girdle. It differs in having a detached finlet behind the dorsal and anal fins. It should be noted that the species of this family have the last dorsal and anal ray more or less thicker and somewhat longer than the preceding ray. In *Decapterus* this ray became detached to form a separate finlet. The development of finlets in some species of Carangidae, evidently appeared independently in different lines of descent as discussed above.

Decapterus punctatus (Agassiz)

Round scad

Caranx punctatus Agassiz in Spix. Selecta genera et species piscium Brasiliensium, p. 108, pl. 56a, fig. 2, 1829 (Brazil)

Decapterus punctatus Jordan and Evermann. Bull. U. S. Nat. Mus. 47(1): 907, 1896 (Cape Cod to Brazil).—Nichols and Breder, Zoologica 9: 110, fig. 146, 1927 (Woods Hole, Mass.; Orient, N.Y.).—Norman, Ann. Mag. Nat. Hist. (10) 16: 251, 1935 (Cape Cod to Brazil: Cape Verde Ids.).—Fowler Bull. Amer. Mus. Nat. Hist. 70(2): 685, fig. 308, 1936 (West Indies).— Longley and Hildebrand, Carnegie Inst. Washington Publ. 535: 75, 1941 (Tortugas, Florida)

D VIII; I 28–32; 1. A II; I 25–27; 1. P 19–21. Scutes 36–44. GR 34–40.

Dorsal rays 28 (1). 29 (2), 30 (5), 31 (3) or 32 (2). Anal rays modally 26 (7), very often 25 (3) or 27 (3). Dorsal spines constant (12). Pectoral rays modally 20 (9), often 19 (2) or 21 (2). Gill rakers long, 12–15+34–40, and a tubercle sometimes at distal end of lower limb; total number of gill rakers and tubercles on both limbs 47–55. Body slender, spindle shaped, depth 19–23 in 12 specimens 67–161 mm. in standard length; caudal peduncle slender. Snout moderate, subequals eye, obtuse. Adipose eyelid well developed, more so posteriorly. Maxillary comparatively rather wide ending under anterior margin of eye; supplemental maxillary moderate. Mouth small, terminal, strongly inclined to a vertical. Teeth small; in one row in both jaws; teeth in upper jaw sparse, confined to anterior part of jaw; in a narrow band on head and shaft of vomer and on palatines, that on shaft extending far backward; in a rather broad band on tongue. Transverse margin of shoulder girdle forming a shallow curve, edged by thick skin forming a moderate, papilla-like projection at its upper and lower extremity. lower papilla somewhat better developed than upper (papillae similar to those in *Selar crumenophthalmus*, except lower one not as well developed). Anus placed near first anal spine. Scales small; antedorsal area scaled to opposite anterior margin of pupil or eye; cheek, opercle and interopercle largely scaled; fins more or less scaled. Anterior curved part of lateral line rather low, continuous rather gradually with posterior straight part; all scales in straight part of 1.1. scute-like, 36–44; scales in curved part normally rounded, not scute-like, 41–55; total number of scales in 1.1. 80–93 (given ranges based on 12 specimens); accessory 1.1. short, curving upward to meet its fellow at a point on midback approximately over posterior margin of head. First dorsal rather high, the spines connected by membrane, the anterior ones rather flexible; first spine moderately short, about one-third as long as third and longest; fourth spine subequal to third or moderately shorter; thence rapidly decreasing backward. The two disconnected anal spines fairly developed. A detached finlet at a short distance behind dorsal and anal consisting of one thick, much branched ray. Dorsal and anal lobe and fold at base of fins moderate; dorsal having 3–6 rays more than anal. Ventral rather short, reaching half the distance from its base to origin of soft anal or a little less; its outer angle slightly behind a vertical through lower pectoral angle. Pectoral rather short, extending a moderate distance beyond end of ventral. Caudal shorter than head.

Upper part dark brownish, lower part silvery with a golden tinge; opercle with a black spot near its upper angle; a row of small dark spots along anterior part of lateral line; a series of faint dusky, transverse streaks on anterior lower part of body. The above color description is from one well preserved specimen from Panama. All other specimens examined are more or less faded and show only traces of one or another of the above color marks.

Gulf specimens examined from Pensacola, off Pepperfish Key, and off Clearwater, Florida. Also from Woods Hole, Massachusetts; Newport, Rhode Island; off Cape Lookout, North Carolina; off Titusville, Florida; Bermuda; Cuba; Puerto Rico; Porto Bello, Panama; Bahia, Brazil. The largest specimen is 190 mm., from Bermuda. The largest Gulf specimen is 175 mm. (7").

This species is easily identified. It is the only Gulf species which has a finlet behind the dorsal and anal fins in combination with well developed scutes in the posterior part of the lateral line. It differs from *macarellus*, the other known species of *Decapterus* in the western Atlantic in having fewer total scales in the lateral line but the scales that are in the form of scutes are greater in *punctatus*. The latter also has fewer pectoral rays.

In 4 specimens of *macarellus*, 3 from Woods Hole and 1 from Puerto Rico, the total number of scales is 126–131; 66–68 in anterior curved part of lateral line; 59–65 in posterior straight part of which the last 28–37 are in form of scutes. Comparing with the counts given above for 12 specimens of *punctatus*, the greatest divergence between the two species is found in the total scale count in the lateral line, including the scutes. However, one specimen from New Smyrna has a total of 108 scales, 64 in curved part and 3 scales and 41 scutes in the straight part. The total number of scales in this variant is, therefore, intermediate of that determined for the few specimens of each species, while the count in the straight part of the l.l. is nearly as in *punctatus*.

The four specimens of *macarellus* have 22–24 pectoral rays, while 13 specimens of *punctatus* have 19–21. The New Smyrna variant has 22. Judged by the few specimens compared, it is reasonable to expect that a study of adequate samples will show that these two species closely approach or overlap in the scale count, and possibly also in the pectoral count.

The data for these few specimens also show that *punctatus* averages fewer dorsal and anal rays and more gill rakers; but the two species well overlap in these characters.

Taking all characters into consideration, the New Smyrna variant seems to be a *macarellus*. Also, all specimens examined from the Gulf are referable to *punctatus*, and on the basis of existing evidence *macarellus* does not occur in the Gulf.

TRACHURUS Rafinesque

Trachurus Rafinesque, Indice D'Ittiologia Siciliana, p. 20, 1810 (genotype *Trachurus saurus* Rafinesque=*Scomber trachurus* Linnaeus by tautonymy)

The nearest relatives of this genus among the Gulf carangids are *Selar* and *Decapterus*. It differs from both in having the anterior scales in the lateral line transversely expanded to a notable extent, and in lacking papillae on the shoulder girdle.

Trachurus lathami Nichols

Rough scad

Trachurus trachurus Jordan and Evermann (in part), Bull. U. S. Nat. Mus. 47(1): 910, pl. 140, fig. 384, 1896 (Newport, R.I.; Pensacola)

Trachurus lathami Nichols, Bull. Amer. Mus. Nat. Hist. 42: 479, 1920 (Orient, Long Island). Nichols and Breder, Zoologica 9: 110, fig. 148, 1927 (Woods Hole, Mass.; Orient, N.Y.).—Nichols, Amer. Mus. Novit. 1067: 1, 1940 (Gulf of Mexico).—Baughman, Trans. Texas Acad. Sci. 24:22, 1941 (Galveston).—Merriman, Copeia 1943 (4): 205 (Newburyport, Mass.).—Gunter, Publ. Inst. Mar. Sci. Univ. Texas 1 (1): 57, 1945 (off Port Aransas, Texas)

D VIII; I 28–33. A II; I 26–30. P 21–22. GR 34–37.

Dorsal spines constant (in 46; for variability in dorsal and anal rays see table 17). Pectoral rays 21 (7) or 22 (5). Gill rakers long, 12–14+34–37, sometimes a tubercle at either end of the arch; total number of gill rakers and tubercles on both limbs 47–51 (in 9 specimens). Slender (see table and discussion below), spindle shaped; caudal peduncle slender. Snout moderate, subequals eye, obtuse. Adipose eyelid well developed, especially its posterior part. Maxillary of moderate width, ending under anterior margin of eye; supplemental maxillary moderate. Mouth medium, well inclined, terminal or subsuperior, lower jaw subequal to upper or a little projecting. Teeth small; virtually in one row in jaws, on head and shaft of vomer and on palatines; row on shaft long; in a narrow band on tongue. Shoulder girdle without papillae. Anus placed near first anal spine. Scales small; antedorsal area scaled to opposite middle or anterior margin of eye; cheek, opercle and interopercle nearly all scaled; fins more or less scaled. (The anterior scales and those on fins are thin and largely missing in most specimens examined, and the preceding statements might need some modification.) Anterior curved part of lateral line moderately rising, rather abruptly continuous with posterior straight part; scales in anterior part 30–37, similar in shape to those in posterior part, transversely expanded to a notable extent, but without a keel and not spinous (the only Gulf species having such scales in anterior part of l.l.), except last 1–3 scales sometimes moderately scute-like; scales in straight part scute-like, keeled and spinous, 31–41; total number of scales in l.l. 66–74; accessory l.l. extending backward to under beginning of soft dorsal. First dorsal rather high, the spines connected by membrane, the anterior ones rather flexible; first spine moderately short, thin; third or fourth spine longest, the two subequal or either one slightly longer than the other; thence rapidly decreasing in length to last. The two disconnected anal spines well developed. Dorsal and anal lobe and fold at base of fins moderate; dorsal having 2–5 more rays than anal. Ventral rather long, reaching to about half the distance from its base to soft anal origin, its outer angle under lower pectoral angle or slightly behind. Pectoral moderately long, reaching over beginning of soft anal origin in large specimens, falling considerably short in smaller fish. Caudal shorter than head.

TABLE XVII

Frequency distribution of the dorsal and anal rays of *Trachurus lathami.*

	dorsal rays						anal rays				
class	28	29	30	31	32	33	26	27	28	29	30
frequency	1	1	13	14	12	4	3	11	20	6	4

Upper part dusky, sometimes with a bluish metallic tinge; lower part light yellowish, golden or silvery; opercle with a marginal spot typically present in the larger specimens, often faint or hardly perceptible; no saliently distinctive color marks.

Gulf specimens examined from off Baffin Bay, Port Aransas and Mustang Island, Texas; off Marsh Island, Mississippi Delta, Breton Sound and Chandeleur Islands, Louisiana; Dauphin Island, Alabama; off Pensacola, Florida. Atlantic coast specimens range from off the coast of Maine to off Melbourne, Florida. The largest specimen examined is 204 mm. (8″), from Woods Hole. The largest Gulf specimen is 180 mm. (7″), from off the Mississippi Delta. This is a pelagic species and is usually not taken in shore seining. The *Pelican* obtained 30 specimens altogether, at 18 stations, with a trawl, in 7–45 fathoms. The species, therefore, apparently also lives at or near the bottom.

TABLE XVIII

Frequency distribution of the total number of scales in the lateral line of *Trachurus lathami.*

	scales								
class	66	67	68	69	70	71	72	73	74
frequency	1	2	2	2	8	11	7	7	7

The frequency distribution of the body depth is given in table 19. The depth was determined at two points. In small specimens the depth averages higher at the ventral base than at the anal origin. In large specimens this relationship is reversed. This difference evidently is a result of a change with growth in the shape of the body. When measured at the anal origin the relative depth increases with growth. At the ventral base the same measurement remains almost stationary, perhaps decreasing slightly with growth.

TABLE XIX

Frequency distribution of body depth in *Trachurus lathami*, measurements taken at two points and segregated by size.

standard length in mm.	distribution 24	25	26	27	28	29	30
			at beginning of anal				
31– 49	1	2	1	1	1	. .	. .
50– 81	....	8	7	4	....	....	....
92–168	....	....	....	1	8	1	2
			at pelvic base				
31– 49	....	....	2	1	2	1	
50– 81	...	....	5	10	5	....	
92–168	....	1	2	3	4	2	..

This species differs from all other Gulf fishes (see also next paragraph), in having the scales in the anterior curved part of the lateral line, as well as those in the posterior part, transversely expanded, with a long tapering wing above and below. They resemble the scales in the posterior part of the lateral line, except that they are neither keeled nor spinous. It is nearest *Selar crumenophthalmus* and differs from that species, besides the structure of the anterior scales, in lacking the two papillae on the shoulder girdle, which are present in the latter species.

Nichols (1940) distinguishes two species of *Trachurus* from the western Atlantic, including the Gulf of Mexico, *lathami* and another species which he identifies with *T. picturatus*, describing the western Atlantic specimens as a new subspecies, *binghami*. He establishes *binghami* on the basis of 54 specimens 12–35 mm. in standard length and one specimen 75 mm., designating the larger specimen as the holotype. According to Nichols *binghami* is more slender than *lathami*, the bend in its lateral line is gentler, the anterior scutes are narrower, and based on an "estimate", it averages a higher number of dorsal rays (32-35) and scutes (76–87). However, Nichols is uncertain whether the holotype is conspecific with the smaller specimens which he examined. Comparing Nichols description with the data given above for *lathami*, we find that the counts of the fin rays and scales of the holotype of *binghami* fall within the range of variation of *lathami*, while the body depth of the type, as well as that of the small specimens, is very close to the range of the latter as given in table 19. Therefore, whatever the status of the smaller specimens examined by Nichols, the holotype of *binghami* might be a variant of *lathami*. If two species of *Trachurus* do exist in the western Atlantic their precise differences still remain to be determined. Among the 28 constituent samples examined by me, comprising 16 specimens from the Gulf and 32 from the Atlantic coast of the United States, I fail to distinguish more than one species of *Trachurus*.

CARANX Lacépède

Caranx Lacépède, Hist. Nat. Poissons 3: 57, 1802 (for a discussion of the status and present use of this name see below)

Spindle shaped, moderately deep; caudal peduncle slender. Snout moderate. Adipose eyelid well developed posteriorly, moderately so anteriorly. Maxillary ending under anterior to posterior margin of eye, moderately broadening posteriorly, wider than pupil; supplemental maxillary of medium width to moderately broad. Mouth medium to rather large, terminal, the jaws subequal or lower jaw slightly projecting. Teeth in a narrow band in upper jaw; in lower jaw virtually in a single row, very few teeth behind outer row directly at symphysis, except in *bartholomaei* in a band; outer teeth in both jaws moderately enlarged; head of vomer with a small patch of teeth, except in *bartholomaei* patch well developed, no backward extension on shaft; palatines and tongue with a band of moderate width or narrow. Anus placed nearer first anal spine than ventral base. Scales small; antedorsal area scaled to a vertical between eye and preopercular margin; a narrow naked strip on midback tapering backward to dorsal origin; cheek and upper part of opercle scaled, larger part of opercle and rest of head naked; fins more or less scaled. Anterior curve in lateral line moderately high, its chord only a little shorter than posterior straight part, except in *crysos;* nearly all or greater part of scales in posterior straight part of l.l. scute-like, notably expanded transversely, heavy, curved, with a longitudinal keel ending in a sharp point directed backward; accessory l.l. extending to opposite posterior margin of head or origin of spinous dorsal. The two dorsal fins well separated in young as well as large specimens; first dorsal rather high (for a carangid), anterior spines rather flexible; normally with 8 spines connected by membrane except last one disconnected and penultimate partly connected; first spine short and slender, third and fourth subequal and longest, last two shortest but stout (in large specimens of *hippos* last 4 spines becoming very short and disconnected); second dorsal with 19–27 segmented rays. The two disconnected anal spines well developed; segmented anal rays 15–24. Dorsal and anal lobe rather high or moderate; fold at base of fins low to high; dorsal having 3–5 rays more than anal. Ventral moderate, reaching about half the distance from its base to soft anal origin, varying a little both ways; its outer angle under lower pectoral angle or slightly more forward. Pectoral strongly falcate, notably long, reaching far beyond soft anal origin. Caudal subequals head, varying a little both ways.

The species of *Caranx* are yellowish or golden, often suffused with a dusky shade on back and fins; without distinctive color marks, except a black spot at posterior margin of opercle present or absent depending on the species and individual variability.

Small specimens of three species, *hippos, latus* and *bartholomaei* are cross banded. Typically with 6–7 black bands against a lighter background, the first band under beginning of spinous dorsal, the last at base of caudal; an oblique band from eye towards origin of dorsal; last band disappearing very early and not sharply marked in the smallest specimens examined.

Small specimens of *crysos* were not examined. Nichols (1938) figures a small specimen of that species, 22 mm. in standard length, as lacking cross bands.

The nearest relatives of *Caranx* among the Gulf carangids, are *Selar*, *Decapterus* and *Trachurus* and it differs from all three in having the anterior scalation less extensive, in addition to other differences as given in the key and the descriptions. The species of *Caranx* reach a much larger size than those of the other three genera.

Baughman (Copeia, 1947, p. 280) records *Caranx ruber* from Port Isabel, Texas. I have no available specimens from the northern Gulf coast. Three specimens examined, one each from Tortugas, Florida, Cuba and Nassau, Bahamas, have: D VIII; I 27–28. A II: I 24. Pectoral 19–21. Gill rakers 13+32–33. Scales in straight part of lateral line 41–45 of which the last 20–27 are keeled scutes. The depth in the 3 specimens 92, 184 and 215 mm. in standard length is 36, 33 and 30, respectively. Chord subtending arch in lateral line only moderately shorter than straight part. This species then falls in the key here given next to *bartholomaei* differing from that species in having a larger number of gill rakers and averaging a slenderer body.

Nomenclature.—Fowler (1936, p. 692) states that Desmarest (in Chenu and Desmarest, 1874, p. 242) designates *Scomber carangus* Bloch as the genotype of *Caranx*. This conclusion is unacceptable. The following is an abstract of the account by Desmarest giving those statements which are pertinent to our question.

"Cette tribu renferme les espèces dans lesquelles la carène de chaque côté de la queue . . . Le genre principal est celui des CARANX, Cuv., Val., . . . On les subdivise en : 1° SAURELS (*Trachurus*, Cuv., Val.), à forme oblongue . . . à ligne latérale armée, sur toute sa longueur . . . le type est le Maquereau batard de la Manche (*Caranx trachurus*, Lacépède) . . . 2° les CARANX PROPREMENT DITS (*Caranx*, Cuv., Val.), qui, avec la forme des Saurels, n'ont de lames ou de boucliers qu'à la dernière partie, ou partie non soudée de la ligne latérale . . . on a donné la description d'une cinquantaine d'espèces de ce groupe [no type designated] . . . 3° les CAROUGES, Cuv., Val., qui, avec la ligne latérale des *Caranx*, ont une forme plus élevée et surtout plus de saillie au front et à la nuque; groupe nombreux en espèces . . . et dont le type est le Carouge des Antilles (*Scomber carougus* [sic] Bloch) . . . 4° les CISTUTES, G. Cuvier, à deuxième dorsale et anale prolongées en faux [no type designated]."

As may be gathered from the above quotation, Chenu and Desmarest, in the main, give a brief outline of Cuvier and Valenciennes' (1833) classification. They divide the genus Caranx into four subgenera by differences in certain morphological characters. Two of these subgenera, *Trachurus* and *Caranx*, they supply with the Latin names used by Cuvier and Valenciennes. For the other two subgenera, les Carouges and les Cistutes, they use French names only. The latter two names are apparently modifications, intentional or unintentional, of Cuvier and Valenciennes "des carangues" (1833, p. 89) and "les citules" (p. 125). They are evidently used as French common names, not latinized, and have no standing in nomenclature. Furthermore, they designate type species for only two subgenera, *Trachurus* and their les Carouges; but not for *Caranx* and their les Cistutes.

The first definite genotype designation for *Caranx* Lacépède seems to be that of Jordan and Gilbert (1882, p. 433) who designate *Scomber speciosus* Forskal, as its type species. Consequently, the name *Caranx* cannot be used for the four species here assigned to it, according to the Rules, since they are not congeneric with *speciosus*, as carangid genera are now treated. However, these species and their congeners have generally been placed in *Caranx* and this treatment is here continued.

This is a case where adherence to the Rules will cause the greater confusion, and it would be well for the International Commission to use its plenary power and assign *Scomber hippos* Linnaeus, as was done later by Jordan and Gilbert (1883, p. 192), or a similar species, as the genotype of *Caranx* Lacépède. That would leave *Scomber speciosus* Forskal as the genotype of *Gnathanodon* Bleeker by monotypy.

Caranx latus Agassiz

Horse-eye jack

Caranx latus Agassiz in Spix, Selecta genera et species piscium Brasiliensium, p. 105, pl. 56b, fig. 1, 1829 (Brazil).—Jordan and Evermann (in part), Bull. U. S. Nat. Mus. 47(1): 923, 1896 (West Indies to Virginia; west coast of Mexico; Panama; Galapagos Archipelago; the figure published as *latus* representing *bartholomaei*).—Nichols, Bull. Amer. Mus. Nat. Hist. 31: 186, 1912 (Havana market, Cuba).—Meek, Field Mus. Nat. Hist. Pub. 10: 101–134 (Costa Rica in fresh water).—Meek and Hildebrand, Field Mus. Nat. Hist. Pub. (zool. ser.) 15(2): 354, pl. 26, fig. 1, 1925 (Atlantic coast of tropical America; said not to occur in Pacific; young figured).—Hildebrand and Schroeder, Bull. U. S. Bur. Fish. 43(1): 223, 1928 (Ocean View, Va.).—Nichols, Amer. Mus. Novit. 967: 3–4, 1937 (young described).—Longley and Hildebrand, Carnegie Inst. Washington Publ. 535: 78 1941 Tortugas, Fla.).—Gunter, Amer. Midl. Nat. 26: 196, 1941 ("reasonably common in Texas offshore waters").—Gunter and Knapp, Texas Jour. Sci. 3: 136, 1951 (Mustang Island, Texas)

Xurel lata Jordan, Evermann and Clark, Rep. U. S. Comm. Fish. 1928 (2): 272, 1930 (listed).—Gunter, Copeia 1935 (1): 40 (Gulf, off Louisiana; Barataria Bay).—Baughman, Trans. Texas Acad. Sci. 24: 22, 1941 (Freeport and Galveston. Texas)

D VIII; I 20–22. A II; I 16–17. P 19–21. Scutes 30–42. GR 14–16.

Dorsal rays modally 21 (in 11), often 20 (4), sometimes 22 (2). Anal rays usually 17 (16), sometimes 16 (1). Pectoral rays modally 20 (10), very often 21 (6), sometimes 19 (1). Gill rakers on upper limb 6–8, upper 3–4 short or tubercle-like in the larger specimens; on lower limb 14–16 with 1–2 tubercles in front or 16–18 altogether; total number of gill rakers and tubercles on both limbs 23–25. Body rather deep, 40–44 in 6 specimens 55–135 mm., 38–41 in 7 specimens 140–270 mm., 34–37 in 4 specimens 277–440 mm. Anterior profile rising steeply and making a rather gradual curve. Maxillary ending under posterior margin of eye or nearly so. Anterior 1–5 scales in straight part of lateral line not definitely scute-like, sometimes all scutes. Dorsal and anal lobe high; fold of skin at their base moderate; the fins moderately scaled (the rays rather easily counted). Spot on opercle faint or absent. Cross bands in young notably wide and the interspaces narrow.

Only two small Gulf specimens, 112–131 mm., examined from Sand Island, Alabama and Laguna Madre, Texas. On the Atlantic coast of the United States from Beaufort, North Carolina to Tortugas, Florida. Also from Nassau, Bahamas: Cuba: Jamaica; Haiti; Puerto Rico; Honduras; Old Providence Island; Curacao: Porto Bello, Panama; Gulf of Venezuela: Bahia, Brazil. The largest specimen is 440 mm. (17″) from Key West.

This species is nearest structurally to *hippos* and differs in having the chest scaled and in the better developed folds encasing the dorsal and anal. The two species differ in the averages of the fin ray and scute counts, but they overlap widely in these characters. The gill raker count is nearly the same in both. Specimens as small as 45 mm. have the chest scaled for its greater part. No attempt was made to distinguish smaller specimens. It is to be expected that small specimens of *latus* in which the scales on the chest have not yet developed, will be difficult to distinguish from *hippos*.

Caranx hippos (Linnaeus)

Common jack, Plate 5, fig. c

Scomber hippos Linnaeus, Syst. Nat., ed. 12, p. 494, 1766 (Charleston, South Carolina)

Caranx hippos Jordan and Evermann, Bull. U. S. Nat. Mus. 47(1): 920, pl. 141, fig. 387, 1896 ("warm seas, generally abundant").—Meek and Hildebrand, Publ. Field Mus. Nat. Hist. Chicago (zool. ser.) 15(2): 350, 1925 (Panama, both coasts).—Bigelow and Welsh, Bull. U. S. Bur. Fish. 40(1): 233, fig. 108, 1925 (Lynn Beach, Massachusetts Bay).—Nichols and Breder, Zoologica 9: 112, fig. 151, 1927 (Woods Hole, Mass.; New York).—Hildebrand and Schroeder, Bull. U. S. Bur. Fish. 43(1): 221, fig. 129, 1928 (Chesapeake Bay).—Fowler, Bull. Amer. Mus. Nat. Hist. 70(2): 696, fig. 312, 1936 ("tropical seas"; young figured).—Gunter, Louisiana Conservation Review 5: 23, 1936 (obtained in shrimp trawls).—Nichols, Amer. Mus. Novit. 976:1, 1937 (young described).—Gunter, Ecol. Mon. 8: 334, 1938 (Louisiana, "Very often the small fish were taken from the bell of the jellyfish, *Stomolophus* sp. Adult fish were common in the summer three or four miles offshore.").—Nichols, Bull. Bingham Ocean. Coll. 7(2): 7, 1939 (young described.)—Baughman, Trans. Texas Acad. Sci. 24:22, 1941 ("common on the Texas coast").—Gunter, Amer. Midl. Nat. 28(2): 311, 1942 (young in fresh water in Florida; listed as euryhalin).—Gunter, Publ. Inst. Mar. Sci. Univ. Texas 1(1): 57 and passim, 1945 (Texas, Louisiana; life history notes)

D VIII; I 19–21. A II; I 15–17. P 20–21. Scutes 24–39. GR 14–15.

Dorsal rays modally 20 (in 14), often 21 (3) or 19 (2). Anal rays modally 16 (13), often 17 (5), sometimes 15 (1). Pectoral rays 20 (9) or 21 (10). Gill rakers on upper limb 7–8, the inner 3–5 in large specimens rather abruptly shorter or tubercle-like; on lower limb 14–15 with 2–3 tubercles; total number of gill rakers and tubercles on both limbs 23–26. Body rather deep, 40–44 in 5 specimens 70–140 mm., 38–42 in 10 specimens 155–285 mm., 33–34 in 3 specimens 315–445 mm., 29 in 1 specimen 747 mm.; anterior profile rather characteristic, rising very steeply and making a strongly convex curve. Maxillary ending under posterior margin of eye or nearly so. A rather large area in front of ventral base and below pectoral base scaleless (the only Gulf species of *Caranx* having this character), except a small patch of scales on ventral aspect, directly in front of ventral base. Anterior 3–10 scales in straight part of lateral line not definitely scutelike. Dorsal and anal lobe high; fold of skin at their base low; the fins moderately scaled for a short distance anteriorly, scaleless in greater part (the rays easily counted).

In 18 specimens 70–444 mm. spinous dorsal as described under the genus; in one specimen 747 mm. last four spines very short. nearly disconnected. the last 2 being hidden under the skin.

Spot at posterior edge of opercle usually well developed. The smaller specimens often with a large black spot on pectoral near its lower posterior margin. developed an interradial membrane. not extending on rays: and an inner black spot at upper pectoral angle. Cross bands in young 6. subequal to or moderately wider than interspaces. The anterior 5 cross bands persist in specimens up to 100 mm. or somewhat larger. becoming faint before they disappear. The oblique band on the nape disappears earlier.

Gulf specimens examined from: Clearwater Bay and Pensacola. Florida: Mississippi: Bayou St. Denis. Tambour Bay, Bay la Mer. Barataria Bay. Grand Isle and Isle

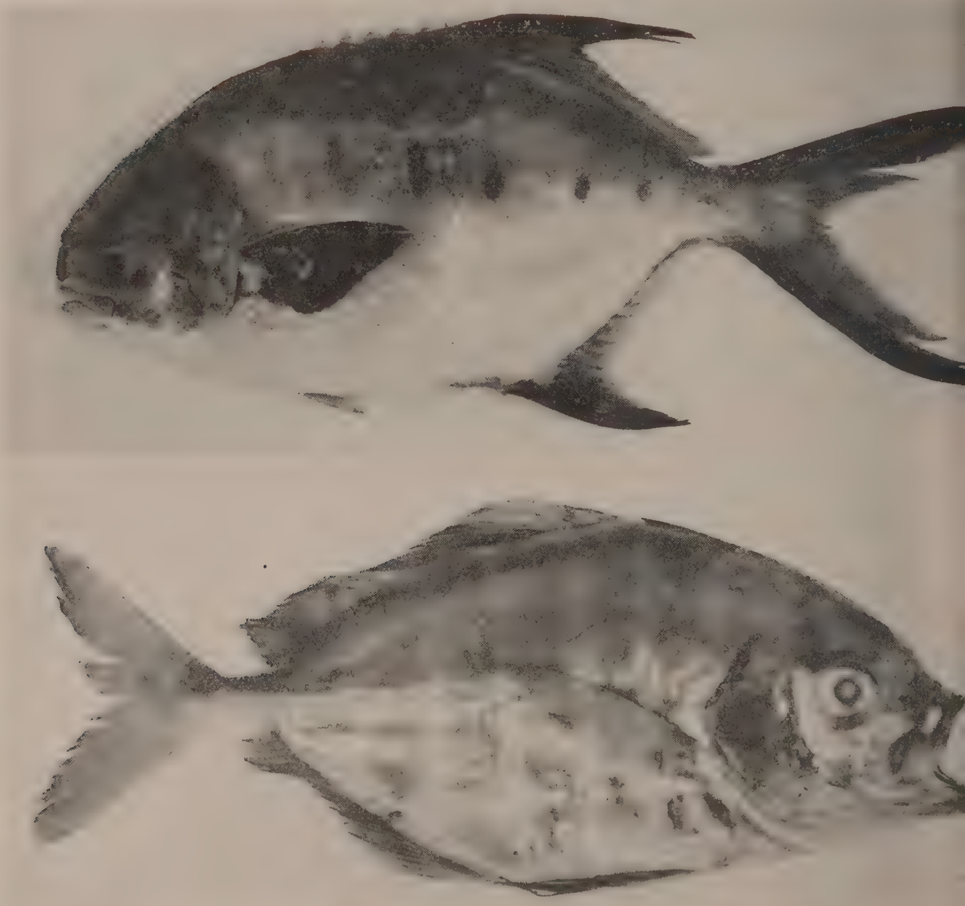


PLATE 5

Fig. a. *Trachinotus marginatus*, 320 mm Uruguay. USNM 87728.

Fig. b. *Uraspis heidi*, 207 mm Off Mississippi Delta. USNM 157566.

Dernière, Louisiana; Galveston, Matagorda Bay, Corpus Christi, Laguna Madre and Brazos Santiago, Texas. On Atlantic coast of the United States from Woods Hole, Massachusetts to Key West, Florida. Also, from Gulf of Campeche; Cuba; Puerto Rico; Curacao; Atlantic coast of Panama and Colombia; Gulf of Venezuela. The largest specimen is 747 mm. (29") from Pensacola. This common species reaches to a considerably larger size.

This species differs from the others in lacking scales on the chest. Structurally it is nearest to *latus* and the differences between them are discussed under the account of that species.

Caranx bartholomaei Cuvier and Valenciennes

Yellow jack

Caranx bartholomaei Cuvier and Valenciennes, Nat. Hist. Poiss. 9: 100, 1833 (Saint Bartholomew Island). —Jordan and Evermann, Bull. U. S. Nat. Mus. 47(1): 919, 1896 ("West Indies, occasionally northward to Florida and North Carolina").

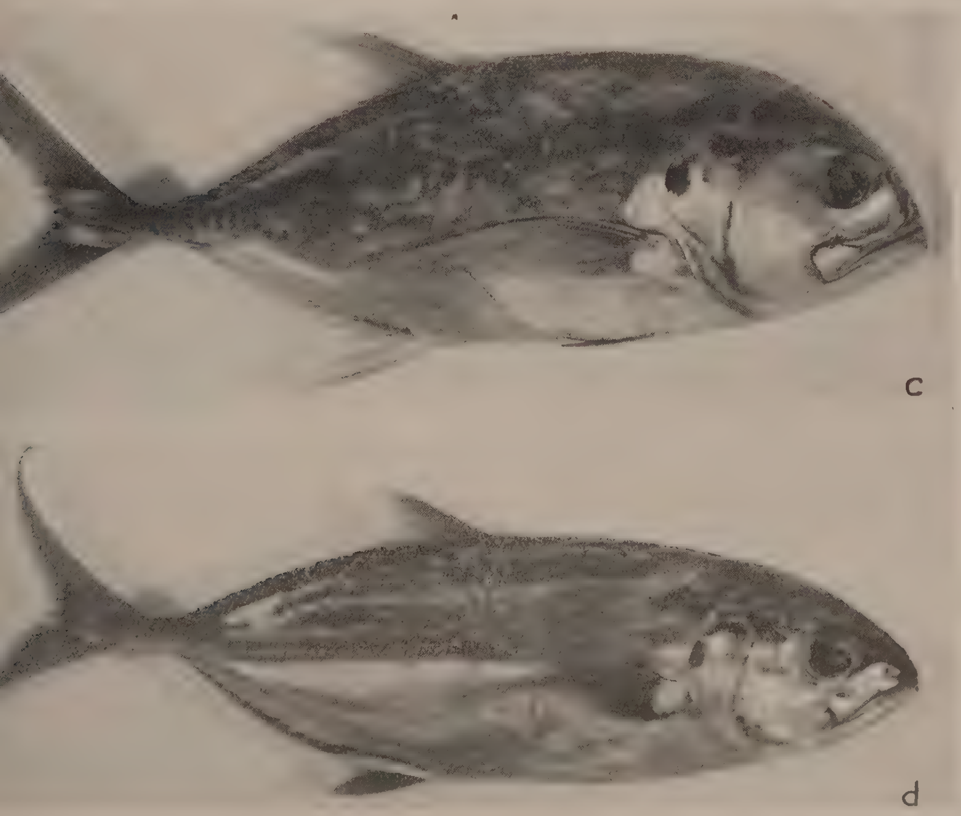


PLATE 5—(Continued)

Fig. c. *Caranx hippos*, 305 mm Woods Hole, Mass. USNM 12681.

Fig. d. *Caranx crysos*, 295 mm Indian Key, Fla. USNM 57224.

Meek and Hildebrand, Publ, Field Mus. Nat. Hist. Chicago (zool. ser.) 15 (2): 351, 1925 (Atlantic coast of Panama).—Nichols and Breder, Zoologica 9: 111, fig. 150, 1927 (Woods Hole).—Nichols, Bull. Bingham Ocean. Coll. 7(2): 3, 1939 (young described).—Longley and Hildebrand, Carnegie Inst. Washington Publ. 535: 78, 1941 (Tortugas, Florida).—Gunter and Knapp, Texas Jour. Sci. 3: 136, 1951 (St. Joseph Island, Texas)

Caranx latus Jordan and Evermann (in part), Bull. U. S. Nat. Mus., no. 47, pt. 4, pl. 142, fig. 389, 1900 (the figure, published as *latus*, representing this species)

D VIII; I 25–27. A II; I 22–24. P 20–21. Scutes 20–31. GR 17–21.

Dorsal rays modally 26 (in 7), often 27 (2) or 25 (1). Anal rays modally 23 (7), often 22 (2) or 24 (1). Pectoral rays predominantly 21 (6), often 20 (3). Gill rakers on upper limb 7–9, upper 3-4 abruptly shorter or tubercle-like in large specimens; on lower limb 17–21 with 1–2 tubercles, or 19–21 altogether; total number of gill rakers and tubercles on both limbs 26–30. Body rather deep, 46–49 in 3 specimens 32–80 mm., 39-42 in 6 specimens 85–165 mm., 33 in 2 specimens 270–355 mm.; anterior profile rising moderately. Maxillary ending under anterior margin of eye. Lower jaw with a narrow band of teeth in front becoming a single row posteriorly; patch of teeth on head of vomer well developed (in other three species here treated teeth in lower jaw virtually in a single series, patch on vomer small). Scutes confined to posterior portion of straight part of lateral line, anterior 12–19 scales not definitely scute like. Dorsal and anal lobe and fold of skin at their base moderate; these fins very densely scaled (the rays counted with difficulty).

No opercular spot in the specimens examined. One small specimen, 30 mm. in standard length from Tortugas, has the cross bands faint, subequal to the interspaces, and 7 in number, instead of 6 as in *hippos* and *latus*. The oblique band behind the eye is represented by a mere trace. The characteristic banded color pattern of the young of *Caranx* possibly disappears early in this species.

Only one small Gulf specimen, 85 mm., examined from Pensacola, Florida. Also from Woods Hole, Massachusetts; Beaufort, North Carolina; Tortugas, Florida; Nassau, Bahamas; Cuba; Jamaica; Porto Bello, Panama. The largest specimen is 355 mm. (14″) from Nassau.

This species differs from its other three congeners here treated in having a higher dorsal and anal count, a greater extent of dentition on the lower jaw and vomer, and in that a considerable extent of the straight part of the lateral line, anteriorly, has ordinary scales, instead of scutes. In the latter character it most nearly approaches *hippos*.

Caranx crysos (Mitchill)

Blue runner, Plate 5, fig. d

Scomber crysos Mitchill, Trans. Lit. Philos. Soc. New York 1:424, pl. 4, fig. 2, 1815 (New York)

Caranx crysos Jordan and Evermann, Bull. U. S. Nat. Mus. 47(1): 921, pl. 142, fig. 388, 1896 (Cape Cod to Brazil).—Meek and Hildebrand, Publ. Field Mus. Nat. Hist. Chicago (zool. ser.) 15(2): 358, pl. 27, 1925 (Atlantic coast of Panama).—Bigelow and Welsh, Bull. U. S. Bur. Fish. 40 (1): 234, fig. 109, 1925 ("Brazil to Cape Cod").—Nichols and Breder, Zoologica 9: 113, fig. 152, 1927 (Woods Hole, Mass.; New York).—Hildebrand and Schroeder, Bull. U. S. Bur. Fish. 43(1): 222, fig.

130, 1928 (Chesapeake Bay).—Nichols, Amer. Mus. Novit. 1014: 1, fig. 1, 1938 (account of young).—Nichols, Bull. Bingham Ocean. Coll. 7(2): 4, 1939 (description of young).—Longley and Hildebrand, Carnegie Inst. Washington Publ. 535: 79, 1941 (Tortugas, Florida)

Paratractus crysos Jordan, Evermann and Clark, Rep. U. S. Comm. Fish. 1928 (2): 272, 1930 (listed).—Gunter, Copeia 1935 (1): 40 (Louisiana; young taken from the bell of *Stomolophus*).—Baughman, Trans. Texas Acad. Sci. 24: 22, 1945 (Port Arthur, Galveston and Freeport, Texas)

D VIII; I 23–24. A II; I 19–21. P 21–23. Scutes 45–54. GR 25–28.

Dorsal rays modally 23 (12), often 24 (4). Anal rays modally 20 (9), very often 19 (7), sometimes 21 (1). Pectoral rays with the mode decidedly at 22 (12), often 21 (2) or 23 (4). Gill rakers 12–14+25–28, sometimes an additional tubercle at either end of the gill arch; total number of gill rakers and tubercles on both limbs 38–42. Body rather slender, 30-36 in 13 specimens 100 295 mm., 29 in 1 specimen 550 mm.; anterior profile rising moderately. Maxillary ending approximately under middle of eye. Anterior curve in lateral line relatively short (as compared with its 3 Gulf congeners), its chord about one and three quarters times in straight part of 1.1.; all scales in straight part of 1.1., except sometimes anterior 1–2, scute-like. Dorsal and anal lobe moderately high; fold at their base well developed, almost entirely encasing low part of fins; these fins densely scaled (the rays counted with difficulty). Spot on opercle usually moderately developed, sometimes faint.

Only three Gulf specimens examined, from Grand Isle, Louisiana and Pensacola, Florida. On the Atlantic coast from Halifax, Nova Scotia to Key West, Florida. Also from Nassau, Bahamas; Cuba; Jamaica; Puerto Rico; Atlantic coasts of Panama and Colombia; Gulf of Venezuela; Brazil. The largest specimen is 550 mm. (22″) from Woods Hole. The largest Gulf specimen is 465 mm. (18″) from Pensacola.

This species differs from its 3 Gulf congeners in having a greater number of gill rakers, a more slender body, a greater average number of pectoral rays and a shorter anterior curve in the lateral line. Concomitant with the latter character it has a larger number of scutes.

HEMICARANX Bleeker

Hemicaranx Bleeker, Versl. Med. Kon. Akad. Wet. Nat. Amsterdam 14: 135, 1862 (genotype *Caranx marginatus* Bleeker by original designation)

This genus is near *Caranx* differing in having a less extensive dentition, a deeper body and narrower maxillary. It is also close to *Chloroscombrus* and *Uraspis* as discussed under their accounts.

Nomenclature. Fowler, in the references cited under the species and in other places, uses the generic name *Alepes*, instead of *Hemicaranx*, for this species. The genotype of *Alepes* Swainson is the wori parah of Russell which formed the basis of Swainson's *Alepes melanoptera*. Fowler states that Russell's species is the same as *Caranx nigripinnis* Day; but Day (1876, p. 225) is uncertain about this identification as he places, in his synonymy of *nigripinnis*, the citation to Russell with a query. Consequently, the status of *Alepes*, as that of its genotype, is in doubt. Now, assuming that Russell's wori parah is the same as Day's *C. nigripinnis* and comparing the latter with our species, Day's figure shows a more elongate fish with a broader maxillary and a higher first dorsal fin. Also, Day describes his *C. nigripinnis* as not having a sheath on the dorsal and anal fins, differing in this respect from our species. All these differences might mean that the two species compared are not congeneric. Therefore, judged by the available evidence, *Alepes melanoptera* Swainson, the type species of its genus, is either unidentifiable at the present time, or else it is generically different from our species. Under these circumstances, to introduce a change in the widely used name of a species on the basis of what must now be regarded as a mere conjecture, does not seem conducive to nomenclatorial stability. Therefore, the more commonly used generic name *Hemicaranx* is here employed to form the name of our species.

Hemicaranx amblyrhynchus (Cuvier and Valenciennes)

Caranx amblyrhynchus Cuvier and Valenciennes, Hist. Nat. Poiss. 9: 100, pl. 248. 1833 (Brazil)

Hemicaranx amblyrhynchus Jordan and Evermann, Bull. U. S. Nat. Mus. 47(1): 912, pl. 141, fig. 386, 1896 (Cape Hatteras to Brazil).—Nichols, Amer. Mus. Novit. 967: 5, 1937 (South Carolina; Florida; young described; suggests that *rhomboides* based on young specimens of *amblyrhynchus*).—Baughman, Copeia 1947(4): 280 (Aransas Bay, Texas).—Baughman, Texas Jour. Sci. 2: 245, 1950 (Galveston and Rockport, Texas)

Hemicaranx rhomboides Meek and Hildebrand, Publ. Field Mus. Nat. Hist. (zool. ser.) 15(2):345 pl. 25, fig. 2, 1925 (Fox Bay, Panama; type reexamined).—Gunter, Publ. Inst. Mar. Sci. Univ. Texas 1(1): 57, 1945 (Aransas Bay, Texas)

Alepes amblyrhynchus Fowler, Proc. Acad. Nat. Sci. Philadelphia 1905: 71 (Rio de Janeiro).—Fowler, Bull. Amer. Mus. Nat. Hist. 70(2): 690, fig. 310, 1936 (Rio de Janeiro, synonymy)

D VII (VIII); I 27–29. A II; I 23–25. P 19–22. Scutes 45–54. GR 19–23.

Dorsal spines usually 7 (in 11), sometimes 8 (1). Dorsal rays modally 28 (7), very often 29 (3) or 27 (2). Anal rays modally 24 (6), very often 25 (4) or 23 (2). Pectoral rays modally 21 (6), often 20 (2), 22 (1) or 19 (1). Gill rakers 8–10+19–23, sometimes an additional tubercle at end of upper limb; total number of gill rakers and tubercles on both limbs 28–33. Body deep, 49–53 in 5 specimens 40–80 mm., 44–48 in 2 specimens 125-145 mm., 40–42 in 5 specimens 150–325 mm., well compressed; upper profile rising steeply but gradually; caudal peduncle slender. Snout short, obtuse. Adipose eyelid moderately developed. Maxillary short and narrow, ending under anterior margin of pupil, its widest part less than pupil diameter; supplemental maxillary narrow. Mouth small, terminal. Teeth small, in a single row in both jaws; vomer with many tiny papillae, without teeth; palatines and tongue with a patch of teeth posteriorly (patch of palatine teeth variable in extent, apparently often appearing late in life as a few small and medium sized specimens examined lacking palatine teeth). Anus placed about halfway between first anal spine and ventral base. Scales small, antedorsal area scaled to opposite preopercular margin; a naked strip on midback tapering to dorsal origin; area between eye and preopercular margin and a small area on upper part of opercle scaled, greater part of opercle and cheek and rest of head naked; chest scaled. Caudal scaled, other fins scaleless. Anterior curved part of lateral line rather high and short, its chord about two and a half times in posterior straight part; usually all scales in posterior part scute-like, often 1–4 normal scales at its anterior end; accessory l.l. reaching nearly to dorsal origin. First dorsal moderate in height, anterior spines rather flexible, connected by membrane except last one; usually with 7 spines; first spine short, third or fourth longest, the two subequal or either one slightly longer, thence rapidly decreasing in length. The two disconnected anal spines moderate. Dorsal and anal lobe very moderately raised in large specimens; fold at their base well developed, sheathing nearly entire fin except distal part of lobe; dorsal having 3–5 rays more than anal. Ventral short in large specimens, extending less than half the distance from its base to soft anal origin; its outer angle below lower pectoral angle or a little behind. Pectoral falcate, long, reaching beyond beginning of soft anal. Caudal longer than head. Golden yellow without distinctive marking, except a black spot on opercle.

Small specimens with 4 dark cross bands, the first under origin of spinous dorsal, the last at a moderate distance in front of end of soft dorsal; the bands slightly narrower than or subequal to interspaces; a cross band on nape less well marked, terminating in a large spot on opercle. Specimens 22 mm. or less are almost uniformly pigmented. The bands are very faint in one 30 mm. specimen. They are well or sharply marked between 35 and 100 mm. They become faint at 125 mm. and are altogether absent at 145 mm. or larger.

Gulf specimens examined from Corpus Christi Bay, Harbor Island, Aransas Pass, Aransas Bay and Galveston, Texas; off Tigre Point, Grand Isle, Barataria Bay and Breton Island, Louisiana; off Gulfport, Mississippi; Pensacola, Florida. Also, off Bull Bay and Charleston, South Carolina; off New Smyrna, Florida; Fox Bay, Colon, Panama (holotype of *H. rhomboides*); Pernambuco, Brazil. The largest specimen is 325 mm. (14″) from Charleston. The largest Gulf specimen is 280 mm (11″) from Pensacola.

Among the Gulf carangids, this species is nearest *Uraspis heidi* and the differences between them are discussed under the account of that species.

H. rhomboides Meek and Hildebrand was separated from *amblyrhynchus* on the basis of the low dorsal and anal fins; but this is an age character in this as well as many other carangid species. The holotype of *rhomboides* agrees with specimens of *amblyrhynchus* of like size, in the height of the fins as well as in other characters.

URASPIS Bleeker

Uraspis Bleeker, Nat. Tijdschr. Ned. Ind. 8:418, 1855 (genotype *Uraspis carangoides* Bleeker by monotypy)

This genus differs from the other carangid genera here treated in having the spinous point of most of the scutes directed forward and the presence of milky white areas in the mouth cavity. Its relationship is discussed further under the account of the species.

Uraspis heidi Fowler

Plate 5, fig. b

Uraspis heidi Fowler, Proc. Acad. Nat. Sci. Philadelphia 90: 150, 1939 (New Jersey)
D VIII; I 29. A 0; I 21. P 23. Scutes 38. GR 14.

Body deep, compressed; contour of back a rather steep, well marked, nearly symmetrical curve from snout to caudal peduncle; lower profile a nearly straight, descending line to anal origin, thence a nearly straight, rather steep line rising to peduncle; caudal peduncle rather slender, subterete (excluding the well developed ridge formed by the scutes). Snout short, obtuse, moderately longer than eye (measured between margins of eyelid). Adipose eyelid moderately developed. Maxillary short, ending under anterior margin of eye, of moderate width, its widest part somewhat wider than pupil; supplemental maxillary moderate. Mouth small; subsuperior, lower jaw moderately projecting, inclined nearly at a 45° angle. Teeth moderately small, in two rows in both jaws, those at symphysis of upper jaw and inner teeth of lower jaw moderately larger than others; no teeth on vomer, palatines and tongue. Gill rakers rather well developed, 6+14. Anus placed about halfway between pelvic base and soft anal origin. Scales small; body all scaled, antedorsal area in large part scaled, the scalation on back extending to an irregular, somewhat transverse line opposite preopercular margin; chest, in front of a nearly vertical line through pelvic base scaleless; area between eye and preopercle scaled, the scalation continued for some distance downward on cheek, an area on upper part of opercle and preopercle scaled, the scalation continuous with that on cheek; rest of head, including snout, interorbital and a strip along midback to dorsal origin scaleless. Caudal partly scaled, other fins scaleless. Anterior curve in 1.1. comparatively long and low, its chord about five-sevenths the length of the straight part; all scales, except first one, in straight part scute-like, the spinous point of the posterior and greater number of scutes directed forward (the only Gulf carangid having this peculiarity): a few of the anterior scutes having weak points directed backward, the spinous points increasing gradually in strength and changing gradually in direction; accessory 1.1. about reaching to opposite dorsal origin. First dorsal low, the first four spines unevenly graduated, the fourth longest, thence rapidly decreasing in length, first spine very short, third moderately shorter than fourth; the spines flexible and connected by membrane, except last one partly disconnected, very short, stout and pungent. The two disconnected anal spines virtually absent in specimen examined, a mere trace of their points hidden under the skin, faintly appreciable with the point of a needle as slight irregularities in the trenchant mid-ventral line. Anterior spine of second dorsal and anal flexible; the two fins, especially the dorsal rather high, the rays very moderately and gradually decreasing in length backward, the anterior rays not forming a definite projecting lobe; fold at their base slightly developed anteriorly, absent posteriorly; dorsal having 8 more rays than anal. Ventral long, tapering, reaching a moderate distance behind anal origin, its outer angle slightly in front of lower pectoral angle. Pectoral slightly falcate, of medium length, reaching to end of curve in 1.1. Caudal a little shorter than head.

Depth 47, head 32, pelvic 33, pectoral 31.

Tongue milky white, the white color tapering backward along bases of gill arches; palate with a similar white, wedge shaped area tapering backward, the head of the wedge expanded sideways; frenum behind upper and lower jaw with a median hyaline area, flanked on each side with a milky white tapering area, in contrast to milky white color rest of mouth cavity largely black; ground color yellowish on upper half, silvery below; a faint trace of 6 dusky cross bands on body, the bands wider than the interspaces; opercle rather dark, without a definite black spot; fins dusky.

The above account is based on one specimen 207 mm.; taken by the "Oregon" off the Mississippi Delta in 32 fathoms, September 24, 1950.

Among the Gulf carangids this species is nearest *Hemicaranx amblyrhynchus*. It differs from the latter as well as all other Gulf carangids in that the spinous point on most scutes is directed forward, instead of backward, and in having milky white areas inside the mouth cavity. It further differs from *H. amblyrhynchus* in having a notably longer ventral, a lower first dorsal, a somewhat wider maxillary, a longer arch in the lateral line, two rows of teeth in the jaws, in lacking teeth on the tongue and palatines, and in having fewer gill rakers, scutes and anal rays, and more pectoral rays.

The type specimen of *U. heidi* was not examined, but the specimen described above substantially agrees with the original description of *heidi*. This species is very near *U. carangoides* Bleeker from the East Indies (see Wakiya, 1924, p. 207), and the precise differences between them remain to be elaborated by the direct comparison of specimens.

CHLOROSCOMBRUS Girard

Chloroscombrus Girard, Proc. Acad. Nat. Sci. Philadelphia 10: 168, 1858 (genotype *Scomber chrysurus* Linnaeus by monotypy, the two species included, *Seriola cosmopolita* Cuv. and Val. and *Chloroscombrus caribbaeus* Girard being synonyms of *Scomber chrysurus* Linnaeus)

This genus is nearest *Hemicaranx* in its characters, form and general appearance. It differs in virtually lacking scutes, in its more extensive dentition and in having the curvature of the ventral contour appreciably better developed than that of the dorsal contour.

Chloroscombrus chrysurus (Linnaeus)

Bumper

Scomber chrysurus Linnaeus, Syst. Nat., ed. 12, p. 494, 1766 (Carolina)

Chloroscombrus caribbaeus Girard, Proc. Ac. Nat. Sci. Philadelphia 10: 168, 1858 (St. Joseph's Island, Texas).—Girard, U. S. and Mex. Bound. Survey, Ichthyology, p. 21, pl. 11, fig. 6, 1859 (St. Joseph's Island, Texas)

Chloroscombrus chrysurus Jordan and Evermann, Bull. U. S. Nat. Mus. 47(1): 938, pl. 145, fig. 394, 1896 (Cape Cod to Brazil).—Nichols, Bull. Amer. Mus. Nat. Hist. 31: 186, 1912 ("Common in Havana market.").—Nichols and Breder, Zoologica 9: 115, fig. 156, 1926 (Orient, New York).—Fowler, Bull. Amer. Mus. Nat. Hist. 70(2): 712, 1936 ("Tropical Atlantic").—Gunter, Louisiana Conservation Review 5: 23, 1937 (catch in shrimp trawls on Louisiana coast).—Gunter, Ecol. Mon. 8: 335, 1938 (Louisiana).—Baughman, Trans. Texas Acad. Sci. 24: 23, 1941 ("Very common on the Texas coast").—Gunter, Publ. Inst. Mar. Sci. Univ. Texas 1(1): 59, and passim, 1945 (Texas; life history notes).—Baughman, Texas Jour. Sci. 2: 246, 1950 (Texas: "The young are found beneath *Stomolophus*.")

D VIII; I 26–28. A II; I 25–27. P 19–20. GR 31–35.

Dorsal rays modally 27 (9), very often 28 (4), often 26 (2). Anal rays usually 27 (7) or 26 (6), often 25 (2). Dorsal spines constant (14). Pectoral rays predominantly 19 (10), very often 20 (4). Gill rakers rather long, 9–11+31–35; total number on both limbs 40–45. Body deep, depth 49–54 in 2 specimens 32–36 mm., 38–45 in 10 specimens 150–305 mm.: well compressed, dorsal and ventral outline rather trenchant, evenly rounded; curvature of ventral profile greater than that of dorsal to a notable extent; caudal peduncle slender. Snout short, somewhat shorter than eye, obtuse. Adipose eyelid rather well developed posteriorly, very moderate anteriorly. Maxillary moderately broad, ending under anterior margin of eye; supplemental maxillary moderate. Mouth small, more inclined to the vertical than the horizontal, superior, lower jaw projecting. Teeth very small, in narrow bands in jaws and on palatines, except in two irregular rows on side of lower jaw; in a medium patch on head of vomer, none on shaft; teeth on tongue covering its greater part, leaving a narrow, marginal, smooth strip. Anus placed a little nearer first anal spine than ventral base. Scales small; antedorsal area scaled to a vertical between eye and preopercular margin; area between eye and preopercle, and upper part of opercle scaled; greater part of cheek and opercle and rest of head scaleless; caudal and pectoral near their base and dorsal and anal lobes moderately scaled, fins otherwise scaleless. Anterior curve in lateral line moderately high, its chord about one and one-half in straight part; 61–68 scales in straight part of 1.1.; scutes rudimentary, not larger than adjacent unmodified scales, keel and blunt spinous point slightly or hardly developed, few, 7–12, confined to caudal peduncle for a variable distance along its middle; accessory 1.1. reaching to under beginning of first dorsal. Spinous dorsal moderate in height, spines connected by membrane, except last spine partly or wholly disconnected; anterior spines rather flexible; first spine short and thin; fourth spine longest, third subequal to it or slightly shorter; thence gradually decreasing to last. The two disconnected anal spines fairly developed. Dorsal and anal lobe very moderate; fold at base of fins rather well developed; dorsal usually having one more ray than anal, often the same number in both fins. Ventral fitting in a well developed groove anteriorly, of moderate length, extending less than half the distance from its base to soft anal origin, its outer angle a little behind a vertical through lower pectoral angle. Pectoral notably long and falcate, reaching well beyond a vertical through origin of soft anal. Caudal longer than head.

Upper part, above a horizontal line through upper margin of eye, dark; below that line light silvery or golden, the contrast between the two shades usually abrupt and striking; a black spot at base of caudal, on upper half, partly on peduncle and partly on fin; posterior margin of opercle usually with a black spot, often faint.

This is a common species taken both in surf seining and in trawling in the open Gulf. Gulf specimens examined are from off Mustang Island, Corpus Christi Bay, Harbor Island, off Aransas Pass, Matagorda Bay and Galveston, Texas; off Marsh Island, Isle Derniere, off Caminada Pass, Grand Isle, Barataria Bay, off Grand Terre, off Bay La Mer, and Breton Island, Louisiana; Dauphin Island, Alabama; Pensacola, Apalachicola Bay, Clearwater Bay, and Boca Grande, Florida. On the Atlantic coast of the United States, from Gravesend Beach, New York to Soldier Key, Florida. Also, from Jamaica; Haiti; Puerto Rico; Antigua, British West Indies; Fort Sherman, Canal Zone; Gulf of Venezuela; Brazil. The largest specimen is 305 mm. (12″) from Brazil. The largest Gulf specimen is 194 mm. (8″) from off Barataria Bay.

The shape of the body—notably compressed with the curvature of the ventral outline greater than that of the dorsal and both outlines evenly rounded—together with the black spot on the caudal peduncle, constitute two features by which this species is readily recognized both in the field and the laboratory. Its relationship is discussed above under the genus.

ALECTIS Rafinesque

Gallus Lacépède, Hist. Nat. Poiss. 4: 583, 1802 (genotype *Gallus virescens* Lacépède by monotypy; preoccupied by *Gallus* Moehring 1758)

Alectis Rafinesque, Analyse de la Nature, p. 84, 1915 (substitute for *Gallus* Lacépède)

Blepharis Cuvier, Regne Animal, t. 2, p. 322, 1817 (genotype *Zeus ciliaris* Bloch by monotypy)

Scyris Cuvier, ibid., ed. 2, t. 2. p. 209, 1829 (genotype *Gallus alexandrinus* Geoffroy by monotypy)

Gallichthys Cuvier and Valenciennes, Hist. Nat. Poiss. 9: 168, 1933 (three species included, *major, chevola* and *aegypticus;* no type designated)

Hynnis Cuvier and Valenciennes, ibid., p. 195 (genotype *Hynnis goreensis* Cuvier and Valenciennes by monotypy)

Blepharichthys Gill, Proc. Acad. Nat. Sci. Philadelphia 14: 436, 1862 (substitute for *Blepharis* Cuvier preoccupied in botany)

Gallichthys Lutken, Spolia Atlantica, p. 604, 1880 (*Blepharis, Scyris* and *Hynnis* placed in synonymy)

Alectis Nichols, Bull. Amer. Mus. Nat. Hist. 42(4): 285, 1920 (account of specimens in American Museum of Natural History)

In the presence of well developed scutes *Alectis* is near *Caranx*. In the extent of scalation it is near *Vomer*. In its body shape and position of the anus, it is intermediate between those two genera. In the development of the first dorsal it is more extreme than *Vomer*. Another specialized feature is the long dorsal and anal filaments. The most plausible explanation seems to be that *Vomer* and *Alectis* represent two independent lines of descent from *Caranx* or a similar genus.

Nomenclature and synonymy.—Fowler (1936) applies the later name *Blepharis* for this genus, stating that: "The type of *Alectis* Rafinesque is virtually *Zeus gallus* Linne." He consequently places *Alectis* in the synonymy of *Selene* Lacépède. As the type of *Alectis* is unquestionably *Gallus virescens* Lacépède, Fowler evidently assumes that *Zeus gallus* Linnaeus and *Gallus virescens* Lacépède refer to the same species. However, this assumption is not in accord with the facts in the case. While Lacépède does place *Zeus gallus* Linnaeus in the synonymy of his *Gallus virescens*, the accounts of these two authors do not at all agree. They evidently refer to two distinct species. Neither account is adequate according to present day standards, but Linnaeus' description of his *Zeus gallus* and Lacépède's account of his *Gallus virescens* more nearly agree with the species here designated as *Selene vomer* and *Alectis crinitus*, respectively. It is evident that Lacépède based his species on certain specimens which he described, some of which at least belonged to *Zeus crinitus* Mitchill or some other species congeneric with it; but his synonymy is partly in error.

A cursory examination of specimens in the National Museum, in a graded size range, from West Africa, the Philippines, the East Indies, Hawaii and the eastern Pacific, in addition to the western Atlantic specimens, leads me to conclude that the above synonymy, as previously determined by Lutken and by Nichols, is acceptable in that the proposed generic names largely represent growth stages of congeneric species which undergo extraordinary changes in the form of the body, head and fins as they increase in size. The species belonging to this genus still remain to be properly determined and distinguished. Because of the very extensive growth changes, it would take adequate samples in graded size ranges to distinguish the species properly at all stages of development. According to our present knowledge only one properly authenticated species exists in the western Atlantic.

Alectis crinitus (Mitchill)

African pompano; threadfish (young), Plate 6, figs. a–c

Zeus crinitus Mitchill. Amer. Jour. Sci. Arts 11: 144, fig., 1826 (Shoreham, N.Y.)

Gallichthys crinitus Lutken, Spolia Atlantica, p. 539 and passim, 1880 (discussion of growth changes, relation to other species and synonymy)

Alectis ciliaris Jordan and Evermann, Bull. U. S. Nat. Mus. 47(1): 931, 1896 ("Tropical America on both coasts north to Cape Cod and Mazatlan").—Nichols, Amer. Mus. Nat. Hist. 42: 286, 1920 (specimens from New York, North Carolina and Japan compared).—Meek and Hildebrand, Publ. Field Mus. Nat. Hist. (zool. ser.) 15(2): 364, 1925 (Atlantic and Pacific coasts of Panama; Virginia; Florida: Hawaii; New South Wales).—Nichols and Breder, Zoologica 9: 113, fig. 153, 1927 (Woods Hole; Orient, Long Island; New York)

Hynnis cubensis Poey, Mem. Hist. Nat. Cuba 2: 235, 1860 (Cuba).—Nichols, Bull. Amer. Mus. Nat. Hist. 42: 289, pl. 19, 1920 (Florida, based on a large mounted specimen)

Alectis indicus Nichols (in part), ibid., p. 292 (concludes that *cubensis* is a synonym of *indicus*)

Blepharis crinitus Fowler, Amer. Mus. Nat. Hist. 70(2): 703. fig. 314, 1936 ("Tropical Atlantic")

D (VII) 0; I 18–19. A (II) 0; I 15–16. P 18–20. GR 14–16.

Dorsal rays predominantly 19 (9) very often 18 (5). Anal rays predominantly 16 (11), often 15 (2). Pectoral rays predominantly 19 (10), often 18 (1) or 20 (1). Gill rakers on upper limb 5–6, 2–3 at end becoming very short or tubercle-like in large specimens; on lower limb 14–16, often with one or two tubercles in front; total number of gill rakers and tubercles on both limbs 19–23. Exceedingly deep in young, becoming oblong with growth (see below); compressed. dorsal and ventral profiles moderately trenchant, except anterior part of head; in the smaller specimens dorsal profile rising very steeply from snout to beginning of soft dorsal, head part of outline moderately rounded, a nearly straight steep line behind head; with growth dorsal profile changing markedly. in large specimens contour of back in front of soft dorsal, to an area over eye, a nearly straight line diverging but moderately from a horizontal (approaching outline of *Vomer* and *Selene*); lower profile well rounded to anal origin; profile at base of dorsal and anal a nearly straight line, the two lines nearly equally inclined. Snout and preorbital moderately long. Adipose eyelid very moderately developed. Maxillary medium, ending approximately under anterior margin of pupil. Mouth of medium extent, well inclined, subsuperior, the lower jaw moderately projecting. Teeth small, in a band at symphysis of jaws, tapering backward, sparse on head of vomer and palatines. none on shaft of vomer; a fairly wide or moderate band on tongue. Anus placed about midway between normal position of first anal spine and ventral base. Scales minute, embedded, difficult to trace; cheek partly scaled, rest of head scaleless; side of belly scaleless, rest of body, to an irregular forwardly curved line running from origin of first dorsal to upper angle of gill opening, largely scaled, except irregular scaleless areas both above and below lateral line. Anterior curve in lateral line high, its chord subequal to straight part; straight part of lateral line with 3-16 nearly normal scales in front and 24–38 scutes, the anterior scutes only moderately modified, becoming fairly modified posteriorly, the keel rather well developed, the spinous points moderate; total number of scales in straight part to end of scutes 36–46, a few normal scales behind scutes to end of hypural (not counted); accessory 1.1, reaching to over posterior margin of head or a little behind. Dorsal and anal changing markedly with growth. First dorsal with 7 short, pungent spines; partly disconnected, disappearing at the surface with growth. Second dorsal having first 7 rays filamentous, disconnected, graduated except the second often subequal to or longer than first, much prolonged, the anterior and longest rays one to four times as long as body, depending on the stage of growth and individual variability. The two separated anal spines short, hinged, disappearing with growth. Soft anal similar to second dorsal, except anterior 5, instead of 7, rays filamentous, disconnected and graduated. (Growth changes of fins described below.) Fold at base of dorsal and anal moderately developed; dorsal having 2–4 more rays than anal. Ventral moderately long, reaching nearly to normal position of first anal spine or moderately short of that point; notably long in the small specimens (see below). Pectoral long and falcate, reaching a little beyond posterior bend in lateral line. Caudal shorter than head.

Silvery or golden, suffused with a brownish tinge above. Color of young as follows: upper part of body with 4 broad cross bands not sharply marked, posterior 3 sometimes continued below, becoming fainter and obliquely placed on lower part of body; a dark transversely elongate blotch at upper posterior edge of opercle; a large black spot at base of prolonged dorsal rays, often also at base of similar anal rays; ventrals and filamentous dorsal and anal rays dark or black. With growth black colors largely disappearing.

Ontogeny.—This species undergoes extraordinary changes with growth. In the following description of such changes the given length refers to the standard length.

The spinous dorsal in 4 specimens 9–23 mm. consists of 7 rather short, pungent, subequal spines, except that the first is slightly shorter. They are only partly connected by a membrane, the distal ends being free. In 2 specimens 9–10 mm. the spines are moderately inclined backward in their normal position; with growth the angle of inclination increases until they come to lie closely apposed to the dorsal contour. The tips of most spines can be raised more or less with a needle in specimens up to about 155 mm. In specimens 185 mm. or larger the spines are not evident at the surface but some of them may be slightly raised under the skin. In the largest specimen, 444 mm., the spines have merged with the dorsal contour which is slightly irregular at the surface. Sometimes the spines have nearly disappeared in specimens as small as 95 mm., so that the tips of most of them can hardly or only slightly be felt with a needle.

The two separated anal spines are present and movable in 6 specimens 9–45 mm. These spines also disappear with growth but the size at disappearance varies greatly with the individual. In the next larger sizes to the above, in 3 specimens 51–76 mm. one of these spines is absent, and both are absent in a specimen 77 mm. The largest specimen with both spines present is 94 mm. Of 8 specimens 102–150 mm., 4 have one spine and in 4 both have disappeared. In 7 specimens 156–444 mm., both spines are absent, except one is present in one fish 187 mm.

The body depth and the pelvic length decrease strikingly with growth. The following gives the progressive change in these two measurements. The length of the specimens measured is given first followed by the number of specimens in each category in parenthesis, then the range of the depth and finally that of the pelvic, both expressed as a percentage of the standard length. In very small specimens the ventral contour of the belly forms a deeply convex curve. The depth in such specimens was measured from the origin of the second dorsal to the apex of the ventral contour. In other specimens the depth was measured from the origin of the second dorsal to the origin of the anal (excluding the 2 separated spines), this distance being on a line somewhat inclined to the vertical. The measurements are as follows: 13 (1), depth 92 and pelvic 87; 20–28 (3), 98–106 and 74–77; 45–51 (2) 94–100 and 64–74; 75–96 (7). 86–99 and 50–55; 98–102 (4), 78–79 and 40–47 except 26 in one from Yucatan: 110-118 (4), 75 86 and 30–43; 129–166 (7), 67–78 and 21–29; 187–223 (3). 59–63 and 17–18; 444 mm. (1), 48 and 15.

It is difficult to determine accurately individual variability and growth changes in the length of the filamentous dorsal and anal rays, because these rays are more or less damaged in most specimens examined. Based on the study of such specimens as appear to have these rays entire or nearly so, the following tentative statements may be made: In specimens up to 157 mm. the longest dorsal rays vary from 2 to 4 times the standard length of the fish. In specimens 166–223 mm. their length is 1 to 2 times the standard length. (In the 444 mm. specimen the dorsal and anal lobes are broken.) The longest anal rays are usually more or less shorter than those of the dorsal.

Specimens examined from New Bedford and Woods Hole, Massachusetts; Newport, Rhode Island; Stonington and Noank, Connecticut; Great South Bay, Long Island; Hungers Wharf, Virginia; Cape Hatteras, Cape Lookout and Cape Fear, North Carolina; Charleston, South Carolina; Key West, Florida; Ambergris Cay, Yucatan. Mexico; Cuba; Jamaica; Colon, Panama; Santos (Market), Brazil. The largest specimen is 540 mm. (22″) from Key West.

The young of this species are recognizable on sight by the shape of the body, the steeply rising anterior profile, in combination with the very long, filamentous soft dorsal and anal rays. In large specimens the shape approaches that of *Selene vomer* and *Vomer setapinnis*, but they are separable by the presence of rather well developed spinous scutes, the less numerous dorsal rays and gill rakers, and the total disappearance of the spinous dorsal at the surface, in addition to other differences.

Synonymy.—Lutken (1880) who published an illuminating study of the remarkable changes that these fishes undergo during growth, uses Mitchill's name *crinitus* for the western Atlantic species. Nevertheless, Jordan and Evermann (1896), without comparing specimens, use Bloch's name *ciliaris* which was proposed for an East Indian fish, to designate this species, and this usage was generally followed by later American authors. However, considering that the East Indian species of fish are different from those in the western Atlantic, with very few rather doubtful exceptions, conclusive evidence is required to prove that any one species is common to both faunas. In such an instance, the burden of proof clearly rests on those who would synonymize names based on specimens of these two almost totally different faunas. To my knowledge no such comparison has been made adequately and convincingly. Therefore, I here use Mitchill's name *crinitus* for the western Atlantic species.

Poey described his *Hynnis cubensis* from a specimen 770 mm. in total length. The large mounted specimen from Florida which Nichols (1920) identified as *Alectis indicus* is 31 inches in standard length, or approximately 892 mm. in total length (calculated on the basis of the published figure). The largest specimen examined by me is 538 mm. The depth of these three specimens measured at the anus, expressed as the number of times it enters the total length, to correspond with the figures given by

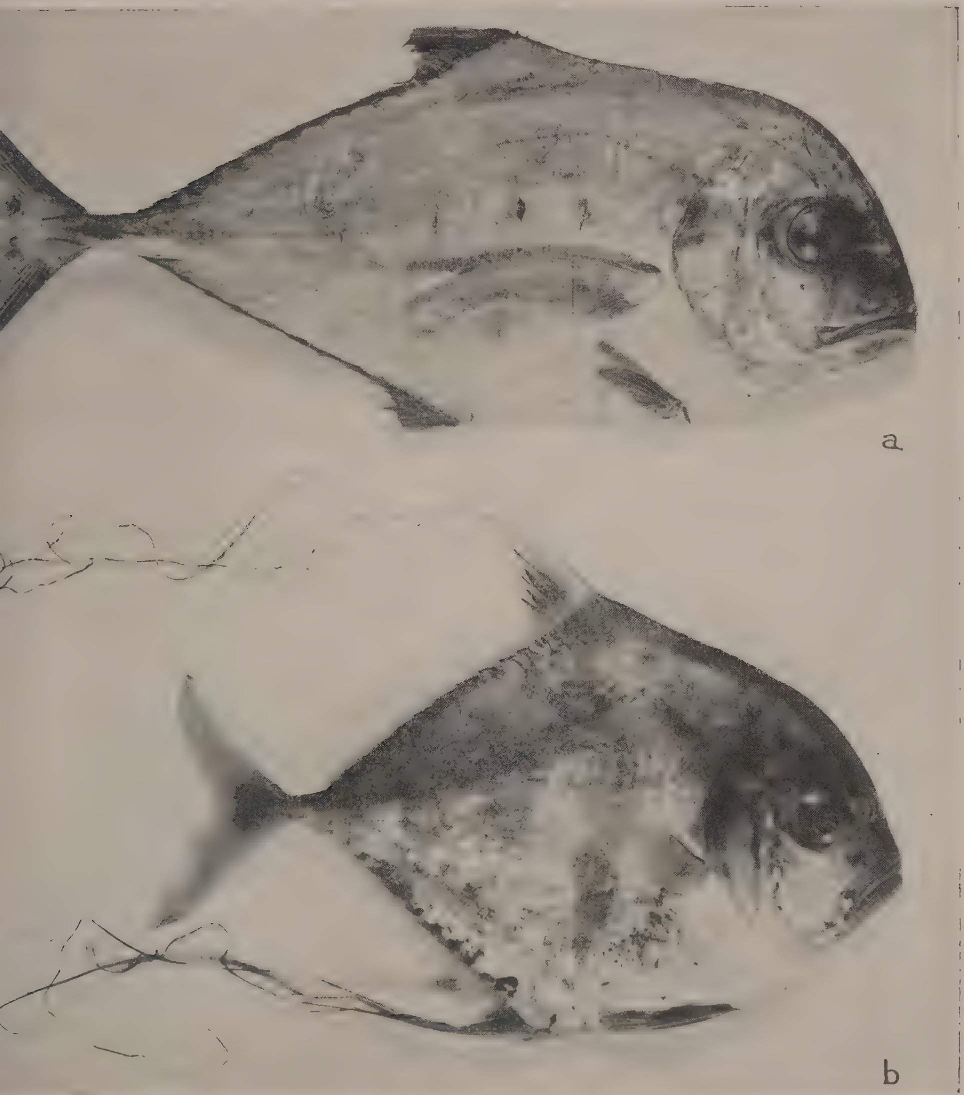


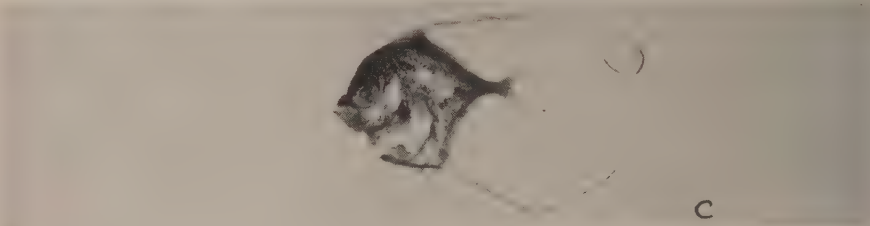
Plate 6

Fig. a. *Alectis crinitus*, 534 mm Key West, Fla. USNM 34855. Dorsal and anal damaged in specimen figured. Judged by published descriptions and figures the anterior rays are not filamentous at this size.

Fig. b. *Alectis crinitus*, 190 mm Cape Lookout, N. C. USNM 74298. All specimens examined having anterior filamentous dorsal and anal rays more or less damaged and tangled or matted.

Poey, is: 538 mm., 2.7 times; 770 mm., 3.0 times; 892 mm., 4.1 times (calculated from the published figure). These three specimens then show a progressive decrease in the relative depth, as was shown above for the smaller specimens. The three specimens also agree in having 19 segmented rays in the dorsal and 16 in the anal. As they come from the same faunal region it is plausible to assume that they belong to the same species. The change in depth of the specimen described by Nichols seems more abrupt than could reasonably be expected, assuming that it belongs to the same species; but part of the difference may be ascribed to its being mounted and perhaps partly to the fact that measurements taken from photographs are not always reliable.

Nichols concludes that his specimen belongs to *indicus* on the basis of some proportional measurements. However, he made his comparison of the 31 inch specimen with one that is only 8 inches long. In view of the remarkable changes in form that these fish undergo with growth, a comparison of only two specimens differing so widely in size, cannot form the basis for a definite conclusion. Considering our present knowledge of these fishes, and geographic distribution in general, it is more likely that Nichols' specimen is a large example of *crinitus*.



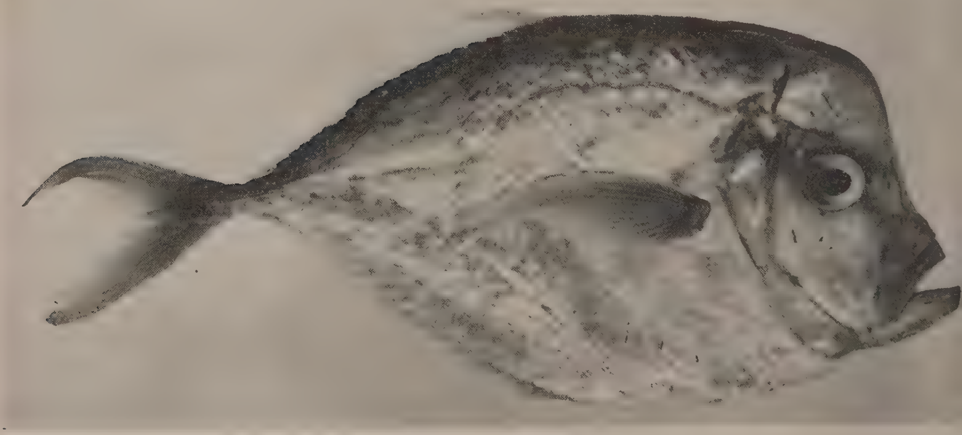


PLATE 6—(Continued)

Fig. c. *Alectis crinitus*, 10 mm in standard length, about 13 mm long. Cape Hatteras, N. C. USNM 148350. Only first dorsal and anal ray greatly prolonged at this size, and maximum prolongation not yet attained.

Fig. d. *Vomer setapinnis*, 225 mm Grand Isle, La. USNM 125793.

VOMER Cuvier

Vomer Cuvier. Regne Animal, p. 318, 1817 (genotype *Zeus setapinnis* Mitchill by monotypy)

This genus is nearest *Selene* and differs from it chiefly in having the anterior dorsal and anal lobes but little elevated, and in body shape. Other characters are discussed under the account of *Vomer setapinnis.*

Vomer setapinnis (Mitchill)

Moonfish, Plate 6, fig. d; Plate 7, fig. a

Zeus setapinnis Mitchill. Trans. Lit. Philos. Soc. New York 1: 384. pl. 1, fig. 9. 1815 (New York)

Vomer setipinnis Jordan and Evermann. Bull. U. S. Nat. Mus. 47(1): 934, pl. 144, fig. 392, 1896 ("Tropical America on both coasts; from Maine to Brazil and Cape San Lucas to Peru").—Nichols. Bull. Amer. Mus. Nat. Hist. 31: 186, 1912 (Havana market; records also another species, *gaboensis*, from same place).—Hildebrand and Schroeder, Bull. U. S. Bur. Fish. 43(1): 226, fig. 132, 1928 (Chesapeake Bay)

Vomer setapinnis Meek and Hildebrand. Publ. Field Mus. Nat. Hist. (zool. ser.) 15(2): 366. pl. 29. fig. 1, 1925 (Atlantic coast of Panama; Pacific coast population described as distinct species, *declivifrons*).—Bigelow and Welsh, Bull. U. S. Bur. Fish. 40(1): 235, fig. 110, 1925 (Gulf of Maine).—Nichols and Breder. Zoologica 9:114, 1926 (Woods Hole. Mass.; Orient, N. Y.).—Fowler. Bull. Amer. Mus. Nat. Hist. 70(2): 707, fig. 317. 1936 ("Tropical seas. Described . . . from American (Middle States) examples.").—Gunter. Louisiana Conservation Review 5: 23, 1936 (common in shrimp trawls in Louisiana).—Gunter, Amer. Nat. 72: 79. 1938 (Louisiana).—Gunter. Ecol. Mon. 8: 334. fig. 11, 1938 (Louisiana).—Baughman, Trans. Texas Acad. Sci. 24:22, 1941 (Galveston to Port Aransas. Texas).—Gunter. Publ. Inst. Mar. Sci. Univ. Texas 1(1): 58. 1945 (Texas: Louisiana; life history notes)

D VIII; I 20–23. A (II) 0; I 17–19. P 17–19. GR 25–29.

Dorsal rays modally 22 (10). often 21 (2) or 23 (2), sometimes 20 (1). Anal rays modally 18 (8). nearly as often 17 (6). sometimes 19 (1). Pectoral rays modally 18 (8). very often 19 (4), sometimes 17 (1). Gill rakers rather long. 5–8+25–29. sometimes a tubercle at end of upper limb: total gill rakers and tubercles on both limbs 31–37 (West Indian specimens seem to average fewer gill rakers: lower limit of range based on such specimens). Very deep, notably so in small specimens, 78–80 in 2 specimens 35–41 mm., 54–67 in 12 specimens 102-280 mm.. 50 in 1 specimen 370 mm.; strongly compressed. outline of head and body trenchant: dorsal profile, from beginning of soft dorsal to an area over middle of eye. a nearly horizontal line: anterior profile from opposite eye upward. a nearly vertical line: the two lines described nearly perpendicular to each other, the angle between the lines rounded: lower profile to anal origin moderately rounded: profile at base of dorsal and anal fins a nearly straight inclined line to peduncle. that at anal base more steeply inclined: peduncle rather slender. Snout long. preorbital broad. Adipose eyelid fairly developed posteriorly. slightly developed anteriorly. Maxillary moderately broad. ending under anterior margin of eye or more forward:

supplemental maxillary moderate. Mouth small, inclined at about 45 degrees, superior, lower jaw projecting. Teeth very small, one row in lower jaw, a narrow band in upper jaw; a rather extensive patch on head of vomer, continued in a long narrow band on shaft; absent on palatines; a rather broad band on tongue, tapering anteriorly. Anus placed notably forward, near ventral base. Scales minute; antedorsal area and head scaleless; upper part, above a horizontal through straight part of lateral line to within a moderate distance from caudal peduncle, only partly and irregularly scaled, for the most part scaleless. Anterior curve in lateral line high, its chord only a little shorter than straight part; scutes nearly confined to caudal peduncle, not evident in the smaller specimens, only moderately developed in larger fish, not larger than adjacent normal scales, the keel only moderately indicated, no definite spinous point posteriorly; scales in straight part of lateral line, including the slightly developed scutes, 62–81; accessory lateral line ending under beginning of first dorsal. Spinous dorsal divisible into two parts, an anterior part consisting of 4 spines connected by membrane (easily torn), rather flexible, and a posterior part having 4 short, stout, pungent, disconnected, widely spaced spines; the anterior part changing markedly with growth; in the young prolonged, filamentous, the second spine a long filament, usually reaching more or less beyond beginning of soft dorsal, sometimes to its middle; the filaments lost early in life, only moderately developed at about 60 mm.; in medium sized specimens the four anterior spines short, slender, flexible, the first about half as long as second and longest, second to fourth graduated; the anterior 4 spines virtually disappearing with growth, sometimes at 240 mm., usually at a larger size; posterior 4 spines becoming relatively shorter with growth, in large specimens lying flat with their posterior surface closely attached to midback, their sharp points protruding backward. The two disconnected anal spines moderately indicated as fixed, projecting points in the small specimens (35 mm. smallest examined), disappearing with growth (at about 125 mm.); third anal spine, the one intimately connected with soft anal, broad and short and with a forward projecting spur in the small specimens, the spur lost early in life, becoming relatively longer and narrower but remaining pungent. Dorsal and anal lobe very moderate or slight, that of dorsal somewhat better developed; fold at their base very slightly developed for a short distance anteriorly; dorsal having 3–6 more rays than anal. Ventral very short, only moderately longer in small specimens, in a comparative way, its outer angle under lower pectoral angle or a little more forward. Pectoral long and falcate, reaching at some distance beyond posterior bend in 1.1. Caudal shorter than head (measured from tip of snout to posteriormost point of opercle).

Preserved specimens golden yellowish or silvery with a metallic bluish tinge above. The smaller specimens with a black spot on opercle, absent in young and disappearing with growth. Young with a rounded, transversely elongate black spot athwart beginning of straight part of lateral line and with transversely oblique, narrow, dusky band over eye. The black spot becomes faint between 60 and 80 mm. and disappears in larger specimens. The band over eye disappears sooner.

Gulf specimens examined from Corpus Christi Bay, Aransas Pass, Freeport and Galveston Bay, Texas; off Caminada Pass, off Grand Isle, Barataria Bay, off Grande Terre, and off Bastian Bay, Louisiana; Mississippi Sound; Pensacola, Florida. On the Atlantic coast specimens range from Magnolia, Massachusetts, to Tortugas, Florida. Also, from Bermuda; Cuba; Haiti; Dominican Republic; Puerto Rico: Colon, Panama; Rio de Janeiro, Brazil. The largest specimen is 370 mm. (15″) from Newport, Rhode Island. The largest Gulf specimen is 170 mm. (7″) from Pensacola.

This species has a striking appearance because of its deep, strongly compressed body, and its unusual, rather irregular shape as compared with the usual body form

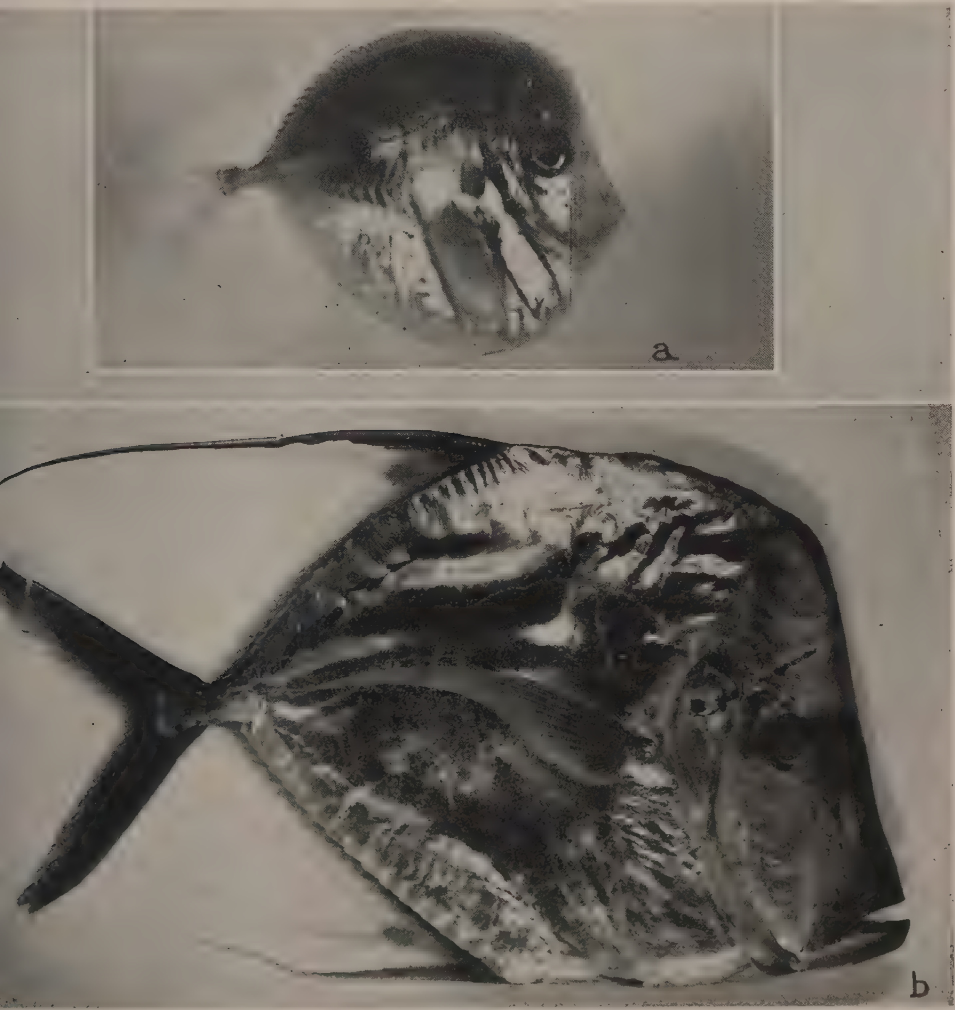


PLATE 7

Fig. a. *Vomer setapinnis*, 41 mm Grand Terre, La. USNM 144109. Second dorsal spine prolonged and anterior dorsal rays moderately longer than in adult in a comparative way, not well indicated in photograph.

Fig. b. *Selene vomer*, 235 mm Newport, R. I. USNM 26028.

of a fish. In appearance and relationship it is near to *Selene vomer* and differs from that species in not having the dorsal and anal lobe greatly prolonged. and in having the anterior profile nearly vertical. instead of well inclined. Young specimens of *V. setapinnis* do not have the first dorsal filaments as long as in *S. vomer*. the ventral is of moderate length. instead of being notably long as in that species. and they have a prominent dark spot on the body.

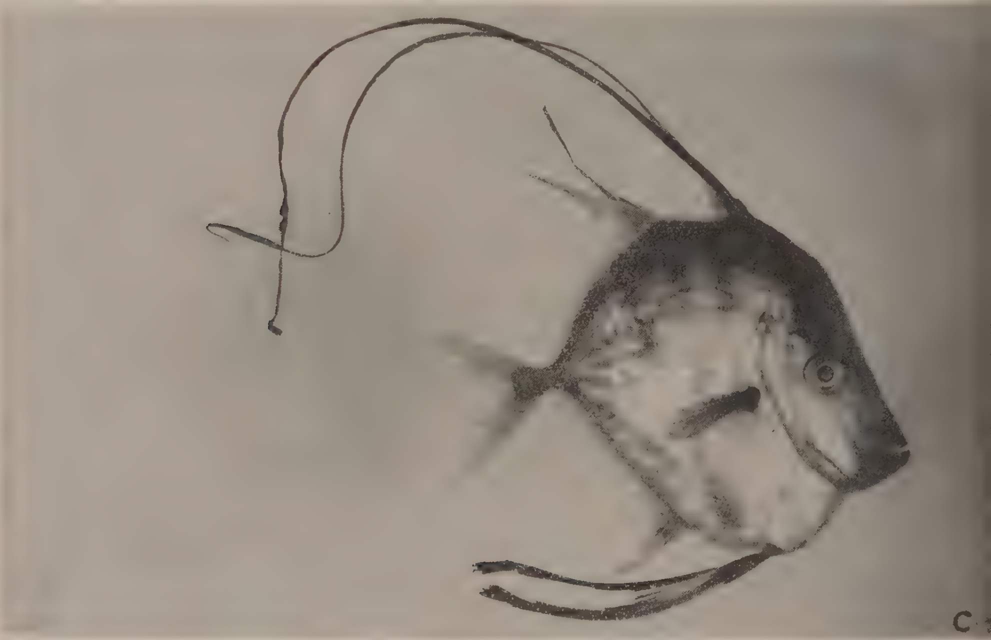


PLATE 7—(Continued)

Fig. c. *Selene vomer*, 34 mm in standard length, about 45 mm long. Beaufort, N. C. USNM 111775. The greatly elongated second and third dorsal spines and ventral fin becoming greatly reduced in large specimens, while the anterior dorsal and anal rays become much prolonged.

SELENE Lacépède

Selene Lacépède. Hist. Nat. Poissons 4: 560. 1802 (genotype *Selene argentea* Lacépède by later designation). Jordan and Gilbert. Bull. U. S. Nat. Mus. 16: 439. 1882 (*Selene argentea* Lacépède = *Zeus vomer* Linnaeus designated as genotype)

Selene is nearest to *Vomer* as indicated under that genus.

Selene vomer (Linnaeus)

Lookdown, Plate 7, figs. b and c

Zeus vomer Linnaeus, Syst. Nat., p. 266, 1758 (America)

Selene vomer Jordan and Evermann. Bull. U. S. Nat. Mus. 47(1): 936, pls. 144 145. figs. 393-393a. 1896 ("Tropical America. on both coasts. from Cape Cod to Brazil, and from Lower California to Peru.").—Nichols, Amer. Mus. Nat. Hist. 31: 186. 1912. (Havana and Cienfuegos markets).—Meek and Hildebrand, Publ. Field Mus. Nat. Hist. Chicago (zool. ser.) 15(2): 372, pl. 31, 1925 (Atlantic coast of Panama; corresponding Pacific population treated as a distinct species. *brevoortii*).—Bigelow and Welsh, Bull. U. S. Bur. Fish. 40(1): 236, 1925 (Gulf of Maine).—Nichols and Breder. Zoologica 9: 115, fig. 155, 1927 (Woods Hole, Mass.; Orient and Sandy Hook Bay, N. Y.).—Hildebrand and Schroeder, Bull. U. S. Bur. Fish. 43(1): 225, fig. 131. 1928 (Chesapeake Bay).—Fowler, Bull. Amer. Mus. Nat. Hist. 70(2): 710, fig. 318, 1936 (New Jersey, North Carolina, West Indies).—Gunter, Louisiana Conservation Review 5: 23, 1936 (catch in shrimp trawls in Louisiana).—Gunter. Ecol. Mon. 8: 334, 1938 (Louisiana).—Gunter, Publ. Inst. Mar. Sci. Univ. Texas 1(1): 58, 1945 (Aransas Bay and open Gulf, Texas).—Baughman, Texas Jour. Sci. 2: 246, 1950 (Texas, "fairly common")

Argyreiosus vomer Baughman. Trans. Texas Acad. Sci. 24: 23. 1941 (Rockport and Port Aransas, Texas, "not especially common")

D VIII; I 21–23. A (II) 0; I 18–20. P 20–21. GR 23–27.

Dorsal rays modally 22 (11), often 23 (4), sometimes 21 (1). Anal rays modally 19 (11), often 18 (4), sometimes 20 (1). Dorsal spines constant (15). Pectoral rays predominantly 20 (11), often 21 (4). Gill rakers rather long, 6–8+23–27, occasionally one tubercle at either end of gill arch; total number of gill rakers and tubercles on both limbs 31–34. Very notably deep, excessively so in small specimens, depth 81–90 in 4 specimens 32–75 mm., 68–80 in 4 specimens 90–130 mm., 68–74 in 5 specimens 145–195 mm., 69–72 in 2 specimens 220–240 mm., 63 in one specimen 317 mm.; strongly compressed, outline of head and body trenchant; dorsal profile, from beginning of soft dorsal to vertical over or behind eye, a nearly horizontal line; anterior profile, from opposite eye upward, a nearly straight, well inclined line, the two lines described forming an obtuse angle when continued, the actual angle rounded; lower profile to anal origin very moderately rounded; profile at base of dorsal and anal fin a nearly straight line, that at anal base a little more steeply inclined; caudal peduncle moderately slender (for a carangid). Snout and preorbital notably long. Adipose eyelid very moderately developed all around. Maxillary broad, ending on a vertical much in front of eye; supplemental maxillary well developed. Mouth small, rather well inclined, superior, lower jaw moderately projecting. Teeth minute, virtually in one row in lower jaw; in a narrow band in upper jaw; in a moderate band on head of vomer, continued in a long, narrow band on shaft; absent on palatines; in a rather broad band on tongue, on its posterior part, tapering anteriorly. Anus placed not far from ventral base. Scales minute; antedorsal area and head scaleless; body nearly all scaled, anterior boundary of scales a rather irregular line, running approximately from origin of first dorsal to upper angle of gill opening. Anterior curve in lateral line moderately high, its chord only a little shorter than straight part; scutes obsolescent, some of posterior scales in straight part of lateral line having the channel somewhat bulging outward, giving some suggestion of a rudimentary keel, but scales not definitely keeled and not spinous, not larger than adjacent ordinary scales; 62–74 scales in straight part of l.l.; accessory lateral line ending under beginning of first dorsal. Spinous dorsal divisible into two parts; anterior part having 4 spines connected by membrane; posterior part having 4 short, stout, pungent, disconnected, widely spaced spines.

increasing but slightly in length from before backward, almost subequal; anterior part changing markedly with growth; in young first and fourth spine of moderate length, either moderately pungent or somewhat flexible, second and third in form of excessively long filaments, the second longer than third, about twice as long as body or longer; with growth spines decreasing in relative length, second and third losing their filamentous structure; in grown specimens the first four spines reduced, short in comparison with most carangid species, pungent or rather flexible, the first spine very short, closely adherent to second, its presence usually detectable only on close scrutiny; second spine longest, thence graduated to fourth; posterior 4 spines similar in young and grown specimens, relatively somewhat smaller in large fish; all dorsal spines persisting with growth. The two disconnected anal spines very moderately developed in young, short, fixed (32 mm. smallest specimen examined): disappearing with growth (at about 150 mm.); third anal spine, the one intimately connected with soft part of fin, pungent; with a forward directed spur near its base, nearly disappearing with growth. Dorsal and anal lobe much prolonged, increasing in relative length with growth, in grown specimens first ray very long, often reaching to end of caudal or beyond, that of dorsal usually longer than that of anal: fold at base of fins poorly developed: dorsal having 3–4 more rays than anal. Ventral differing strikingly with size, greatly prolonged in young, nearly as long as body, very short in large specimens, its outer angle considerably in advance of lower pectoral angle. Pectoral notably long and falcate, reaching to within a moderate distance of caudal peduncle. Caudal shorter than head (measured as in *V. setapinnis* above).

Silvery or golden; back, above lateral line, with a metallic bluish tinge: first prolonged dorsal and anal ray often blackish: no distinctive color marks. Young having ventral and prolonged second and third dorsal spines, black, and with dusky somewhat oblique cross band; a band over eye, continued and tapering below eye; 4 or 5 interrupted bands on body usually very faint.

Gulf specimens examined from Harbor Island and Aransas Pass, Texas; Barataria Bay, Louisiana: Pensacola, Florida. On the Atlantic coast from Staten Island, New York, to Cape Sable, Florida. Also, from Tampico, Mexico; Cuba; Jamaica; Surinam: Gulf of Venezuela: Rio de Janeiro and Pernambuco, Brazil. The largest specimen is 317 mm. (12″) from Jamaica. The largest Gulf specimen is 195 mm. (8″) from Pensacola.

This species has a striking, unusual appearance, similar to that of *Vomer setapinnis* and the differences between the two species are discussed under the account of that species.

OLIGOPLITES Gill

Oligoplites Gill, Proc. Acad. Nat. Sci. Philadelphia 15: 166, 1863 (genotype *Oligoplites saurus* (Bloch and Schneider) by later designation).—Jordan and Evermann, Bull. U. S. Nat. Mus. 47(1): 898. 1896 (*O. occidentalis* Gill=*Oligoplites saurus* (Bloch and Schneider) designated as genotype)

This genus has an unusual combination of characters, namely, acicular embedded scales, lack of scutes, many finlet-like dorsal and anal rays, a non-protractile premaxillary and an unusually narrow maxillary. It is evidently not closely related to any one of the other carangid genera here treated. As far as external characters go, it has more in common with the scombrids. The non-protractile maxillary is as in the scombrids and the narrow maxillary nearly as in those genera. The finlets are nearly as in the Scombridae, except that they are partly connected. The acicular, embedded scales are almost like those on the cheek of *Sarda* and *Euthynnus*.

Oligoplites saurus (Bloch and Schneider)

Leatherjacket

Scomber saurus Bloch and Schneider, Syst. Ichthy., p. 32, 1801 (Jamaica).

Oligoplites occidentalis Gill (not *Gasterosteus occidentalis* Linnaeus, according to Jordan and Gilbert, 1882), Proc. Acad. Nat. Sci. Philadelphia 15: 166, 1863 (Caribbean Sea)

Oligoplites saurus Jordan and Gilbert, Bull. U. S. Nat. Mus. 16: 973 and 447, 1882 ("Both coasts of Central America, and West Indies, north to New York and Lower California").—Jordan and Evermann, ibid., no. 47, pt. 1, p. 989, pl. 138, fig. 378, 1896 (same distribution as preceding).—Meek and Hildebrand, Publ. Field Mus. Nat. Hist. Chicago (zool. ser.) 15(2): 390, pl. 39, fig. 1, 1925 (Atlantic and Pacific coasts of Panama).—Nichols and Breder, Zoologica 9: 108, 1927 (Woods Hole, Mass.; New York).—Hildebrand and Schroeder, Bull. U. S. Bur. Fish. 43(1): 219, fig. 128, 1928 (Chesapeake Bay).—Baughman, Trans. Texas Acad. Sci. 24:23, 1941 (Texas).—Breder, Copeia 1942 (4): 267 (behavior).—Gunter, Publ. Inst. Mar. Sci. Univ. Texas 1(1): 60, 1945 (Texas).—Schultz, Jour. Washington Acad. Sci. 35:334, 1945 (Woods Hole, Mass. to Montevideo, including the West Indies; corresponding Pacific population treated as distinct subspecies)

D V (VI); I 19–21. A II: I 18–21. P 15–17. GR 13–15.

Dorsal rays modally 20 (15), often 19 (3), sometimes 21 (1). Anal rays modally 20 (10), very often 19 (6), sometimes 18 (1) or 21 (2). Dorsal spines normally 5 (18), sometimes 6 (1). Pectoral rays modally 16 (10), very often 17 (7), sometimes 15 (2). Gill rakers on upper limb 6–9, 1-4 at end short or tubercle-like; on lower limb 13–15 gill rakers with an occasional tubercle in front; total number of gill rakers and tubercles on both limbs 20–24. Elongate, spindle shaped, well compressed, moderately trenchant, except lower profile in front of anal; caudal peduncle moderate, compressed. Snout medium, rather pointed. Adipose eyelid very moderate. Premaxillary not protractile (the only carangid genus here treated having this character). Maxillary long, narrow, characteristically curved distally, ending under posterior margin of eye or a little short. Mouth large, oblique, subterminal, lower jaw slightly projecting. Teeth moderately small; in two rows in jaws, the rows characteristically well separated; a rather wide band on vomer, tapering backward, of medium length; palatine band of teeth medium; tongue nearly all covered with granular teeth, except a narrow marginal strip. Anus placed near first anal spine. Scales acicular, long and very narrow (the only Gulf species having this type of scales); well embedded, but their outlines visible at surface; body and antedorsal area scaled to opposite preopercular margin; head and fins naked. Lateral line making a fairly marked upward angle at a moderate distance from its beginning, thence descending moderately and merging imperceptibly with posterior straight part; no scutes; accessory l.l. short, extending but slightly backward. First dorsal normally with 5 spines detached from one another, short, pungent, increasing moderately in length from first to last; in small specimens spines relatively better developed, longer and stouter, partly attached to one another, the fifth (or sixth) also partly attached to soft dorsal. Anal similar to dorsal in structure and development, the first two spines detached and moderately developed in large specimens. Posterior dorsal and anal rays, having a characteristic structure, the base comparatively narrow, fanning out distally with a profusion of branches into a wider expanse, each ray partly detached from adjacent ones, presenting gross impression of a series of finlets partly attached: transition from anterior and fewer normal rays to posterior and more numerous modified rays gradual; anterior dorsal and anal rays moderately elevated; fold at their base obsolescent, very slightly indicated for a short distance anteriorly; majority of specimens having same number of rays in dorsal and anal, often dorsal having 1 2 rays more, sometimes anal having 1 more than dorsal. Ventral moderate reaching to about half the distance from its base to soft anal origin; its outer angle under lower pectoral angle. Pectoral short, reaching a vertical through end of ventral or a little short. Caudal subequal to head length.

In preserved specimens body and head above a lengthwise line through upper angle of opercle dusky or with metallic bluish sheen; the lower part silvery or golden: or silvery nearly all over; the fins yellowish; no distinctive color marks.

Gulf specimens examined from Corpus Christi Pass, Corpus Christi Bay, Mustang Island, Aransas Pass, Harbor Island, St. Joseph Island, Galveston and Dickinson Lake, Texas; Isle Derniere, Barataria Bay and Bay La Mer, Louisiana; off Gulfport, Mississippi; Sand Island, Alabama; Pensacola, St. Joseph Bay, Apalachicola Bay, Ochlockonee Bay, and Tampa Bay, Florida. Also, Woods Hole, Massachusetts; Newport and Wickford, Rhode Island; Spring Lake, New Jersey; Key West and Tortugas, Florida; Cuba; Jamaica; Puerto Rico; Colon reef, Panama; Puerto Colombia. The largest specimen is 282 mm. (11″), from Cuba. The largest Gulf specimen is 241 mm. (9″) from Pensacola.

This species is easily separable from all Gulf coast fishes by the long, narrow, needle-shaped or spicule-like scales which are embedded in the skin, but the outlines of which are visible at the surface. Other unusual features are the non-protractile upper jaw, and the structure of most dorsal and anal rays which are fan-shaped and in the form of finlets attached to one another at their bases. Some other species of *Oligoplites* occur in the West Indies and Central and South America and also on the west coast, but this is the only species found in the Gulf.

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A REGULATON TO INCREASE THE YIELD OF THE NEW ENGLAND HADDOCK FISHERY

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The New England ground-fish fishery has been an important industry since the earliest period in this country's history. In the early days the fish were taken with hook and line, first with hand lines and later with line trawls. In both of these methods baited hooks are used.

In 1905, the fishing on New England banks was revolutionized by the introduction of the otter trawl. This new method met with a great deal of opposition from many members of the industry. They maintained that this new device with its heavy otter boards and wide dragging net would destroy the fishery by killing the small fish and ruining the bottom itself. They foresaw the destruction of the bottom food and natural habitat of the important ground-fish.

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[1] In the absence of Dr. Graham the paper was read by William H. Massman.

In spite of this opposition the fleet of trawlers increased slowly from 1905 to 1925 (Herrington, 1932) when the filleting of cod and haddock was initiated. This new marketing procedure greatly increaseed the demand for haddock which formerly had only a limited market. As a result of this the fleet of otter trawlers was greatly expanded until in 1930 there were 323 working out of New England ports. Today there are more than 600 otter trawlers of various sizes landing at New England ports and practically no large line trawlers—only two remain in Boston.

Opposition to the otter trawl is still heard but this gear is now accepted as the standard method of fishing for ground-fish by the New England fleet. There is no evidence to prove or disprove the theory that this trawl is damaging to the food and habitat of ground-fish.

The other objection to the otter trawl, that it destroys large quantities of small fish, is valid. It does destroy large quantities of immaure fish. Herrington (1932) reported that in the years 1913 and 1930-31 otter trawlers fishing out of New England ports captured between two and three times as many undersized or trash haddock as marketable haddock. In 1930 there were 37 million haddock landed while somewhere between 70 million and 90 million undersized haddock were caught and destroyed at sea. This destruction continues. During the last 5 years the annual destruction of small haddock by the New England fleet of otter trawlers has averaged over five million pounds.

Because of present socio-economic conditions there appears to be no way to provide a utilization of this now wasted food resource. Under present economic conditions it is not profitable for the haddock fishermen to land these small haddock which are caught in such great numbers. There remains only the possibility of preventing their capture.

We are now faced with the problem of whether this destruction of baby scrod is detrimental to the haddock fishery. Has the great wastage of undersized fish contributed to the decline of the New England haddock fishery and does the continued destruction of these sizes threaten present production?

Let us examine first the record of this fishery since the start of intensive fishing by otter trawlers. As the demand for haddock increased fishing was intensified and landings increased accordingly.

Until 1928 haddock was plentiful on Georges Bank (off Cape Cod) and most of the catch was taken there.

A peak was reached in 1929 when over 250 million pounds of haddock were landed in New England ports. About 223 million pounds of this were taken on Georges Bank. During the five following years there was a rapid decline in landings from Georges Bank, reaching the alarming figure of 50 million pounds in 1934. This was due to a scarcity of fish. In that year only about one-third as many haddock were caught per day's fishing as in earlier years.

Because of the scarcity of fish on Georges Bank the trawlers extended their fishing to the Nova Scotian Banks. In that year (1934) almost twice as much haddock was landed in the New England ports from Nova Scotian Banks as from Georges Bank. Fishing on these more distant banks, of course, involves longer trips with greater production costs. Furthermore, the quality of the fish suffers when too great a time elapses between catching and landing.

In 1934 it appeared certain that the haddock fishery on the New England Banks was doomed unless drastic measures were taken to conserve the rapidly depleting stocks of fish. However, 1934 proved to be a low point in the production of haddock from Georges Bank. The records show that from 1934 to 1941 there was a rather steady increase in landings from Georges Bank from the low figure of 50 million pounds to a value of 122 million pounds. Furthermore these landings were not made at the expense of a diminishing stock. The catch per day's fishing also increased during that period from 10 thousand pounds to 17 thousand pounds. The Georges Bank haddock stocks effected a partial recovery without the aid of man. The fishing effort was intense during this period, and rather constant from year to year. Evidently the decline in the Georges Bank haddock stock in the thirties was due partly to natural causes. Likewise, natural causes probably brought about an improvement in the stocks later in the face of continued fishing pressure.

However, the annual production of Georges Bank has never returned to the high values attained in the late twenties nor has the index of abundance. Intensive fishing is holding the stocks at a reduced level. The average annual landings for the past 10 years was 96 million pounds while the annual catch per day's fishing averaged 15.1 thousand pounds. The year to year landings and indices of abundance over the past 10 years do not show any definite trends either downward or upward. We must conclude that the Georges Bank haddock fishery has reached a stage of equilibrium. The annual production, the fishing effort, and the abundance of stock have entered a rather stable state when viewed over a period of a number of years. Fluctuations occur in accordance with fluctuations in recruitment due to natural causes but for the long term there seems to be a certain stability.

Under present socio-economic conditions it is apparently less profitable for fishermen to fish the Georges Bank stocks below their present level than to move to more distant banks of higher abundance.

Thus, without any management, it is probable that the haddock production on Georges Bank would continue at about its present level, barring any drastic change in the socio-economic relations or the occurrence of some unusual natural phenomenon.

The problem, then, for the fishery managers is to determine whether the present average annual production could be increased by some management procedure. Is it possible to stabilize the fishery at a higher level of production? If so, how can this be accomplished?

The Fish and Wildlife Service initiated an intensive investigation of the haddock fishery in 1931. Through this program which was developed and carried on for many years by W. C. Herrington and continued by Howard A. Schuck, a fine body of statistics has been accumulated on this fishery. In the study of the vast quantity of data collected on the New England haddock fishery, attention was directed primarily toward the analysis of the stocks on Georges Bank since that bank is the most important to New England because of its proximity

Data now available for the Georges Bank haddock for the years 1931 to the present include accurate information in landings, by pounds, numbers, and sizes of fish; on year-class strength, growth rate, mortality rate, index of abundance, and degree of independence of stock.

As a result of these investigations the Fish and Wildlife Service has for many years advocated a minimum mesh size for vessels fishing haddock on Georges Bank (Herrington, 1932, 1936, 1941: Schuck, 1947, 1948; Royce and Schuck, 1950). However, no regulatory measures were ever taken and the waste of small fish continued year after year.

At the first meeting of the International Commission for the Northwest Atlantic Fisheries at Washington, D. C., in April 1951 this issue received considerable attention. The Commission agreed that the waste of small fish should be stopped. The question was raised, however, as to whether it was economic to select a mesh size which would protect undersized fish which are now being landed, as well as the fish which are discarded at sea.

A group of Canadian and American scientific advisers was instructed to review the whole problem, to formulate a regulation, and to develop a research program to be carried on before and after regulation in order to assess accurately the effects of the regulation.

The group consists of members of the Fishery Research Board of Canada and members of the Fish and Wildlife Service of the United States. This group first explored the various possibilities of increasing the level of production.

There seemed to be no reason to recommend a closed season for Georges Bank. There is no evidence to indicate that the loss of production during the closed period would be more than compensated for by any increase in weight which the fish might attain during that protective period.

There is also no evidence to indicate that protection of spawning fish would be beneficial. Fluctuation in recruitment seems to be unrelated to size of spawning population. Schuck's unpublished data show that recruitment as expressed by abundance of 2-year-old haddock varies as much as 35 times during a period in which the spawning population remains comparatively uniform. Fluctuations in recruitment due to environmental conditions are so great that it is not possible to assess the importance to recruitment of size of spawning stock at this time.

There remains the problem of the great waste of immature haddock which are being discarded at sea. Is this jeopardizing the full utilization of the haddock resource? Obviously it has not had the extreme effects which were feared back in 1934. However, we must consider the possibility of increasing the landings by elimination of this tremendous waste.

The destruction of a certain number of young fish does not necessarily result in a reduction in total landings. Much of the information necessary to appraise the effect of this destruction of the Georges Bank haddock population is now at hand. Details of this study will be published by Schuck and Widrig.

First of all it is now known that the haddock stocks on Georges Bank are rather independent of those on neighboring banks. Peculiarities of growth and vertebral counts, as well as limited marking experiments, show this (Herrington, 1944; Needler, 1930; Schroeder, 1942; Vladykov, 1935; Schuck and Arnold, 1951; Clark and Vladykov, ms.). The discreteness of the Georges Bank stock greatly facilitates the study of these populations.

The growth rate of Georges Bank haddock is unusually high, especially in the first few years of life (Schuck and Arnold, 1951). There is a corresponding rapid increase in weight during these years. Thus great benefits might be expected by saving these immature fish.

Schuck has determined the total mortality rate of Georges Bank haddock for 3-year-old and older fish to be about 45 per cent per year.

Unfortunately, it is not possible to separate the mortality due to natural causes from that due to fishing. However, it has been found that lack of accurate information on natural mortality rate is not too serious in the study of this particular problem.

Widrig (unpublished manuscript) studied the effect of varying the age at which the haddock are first captured. He constructed a number of theoretical models to show the expected yield from a year class throughout its entire life based on the known growth rate of Georges Bank haddock and a total mortality rate of 45 per cent. He constructed models for carrying proportions of natural and fishing mortality.

If the natural mortality is very low it pays to leave the fish in the sea until they have attained most of their growth. The chances of their being available later are great. If the natural mortality is very high it pays to catch the fish at a very early age. The chances, then, of their being in the sea at a later date are slight.

For purposes of argument it was necessary to assume a natural mortality rate. It was the opinion of the various biologists studying this problem that the natural mortality rate was not likely to be more than 15 per cent. With such a natural mortality rate and with present fishing effort the highest yield would result if the fish were first captured at the age of 3 years or a little older. This is assuming that a net is used which has a 50 per cent selection point for 3-year-old fish. That is, 50 per cent of the 3-year-olds entering the net are retained and at each larger size an increasing percentage is retained.

The present age of first capture of haddock on Georges Bank is about 1½ years and most of the fish of this age are discarded. Thus, on the basis of these above theoretical considerations the present fishing methods are definitely detrimental to the production of the fishery. The age of first capture should be advanced by about 1½ years to bring about the maximum utilization of these stocks. This can be done by increasing the size of mesh used in the otter trawls.

The above calculations assume a natural mortality rate of 15 per cent. Widrig's figures show that if the natural mortality rate is more than 15 per cent very little change will result by advancing the age of first capture. On the other hand if the natural mortality is less than 15 per cent a considerably greater advantage will result in any advance of first age of capture over the present one. Thus, there will be nothing to lose and possibly much to gain by advancing the age of first capture, whatever the natural mortality.

Since some fish between the ages of 1½ and 3 years are now landed, advancing the age of first capture to age 3 would have a temporary adverse effect on landings. Widrig calculated the annual changes which would result in total landings if the age of first capture were suddenly changed from the present 1½ years to the theoretical optimum of 3 years. The first year the reduction in total landings would amount to about 25 per cent. The second year the reduction would be about 15 per cent. Not until the third year could any benefit be expected to result. In succeeding years there would be an increasing benefit until a new equilibrium would be established when production would be increased by about 50 per cent over present landings.

The calculations hold only for an average year, of course. Natural fluctuations in abundance might mask the effect of the increased mesh size in any particular year. The effect would be evident to the fisherman only over a number of years although the biologist could assess its effect on year classes of known strengths immediately.

An expected increase in production of 50 per cent would definitely warrant a regulation of the fishery. However, the initial consequences of such a step as outlined would work a considerable hardship on the industry during the first 2 years, especially if enactment of a regulation happened to coincide with a year of low natural abundance.

For this reason it was considered unwise to recommend advancing the age of first capture to age 3 at this time. Rather, it was decided to select an age which would have the effect of catching hardly any of the fish now being discarded and continuing to catch about 90 per cent by weight of those fish which are now landed. Widrig calculated this age to be a little less than 2½ years. His theoretical models show that in this case the decline in landings the first year would amount to less than 10 per cent and by the second year would be back to average. In following years there would be an increasing benefit reaching a value of about 35 per cent about 6 years after the change is made. By this method it is hoped that the fishery can be brought into a new equilibrium at a higher level of production without decreasing the annual landings materially during the period of adjustment.

The feasibility of advancing the age of first capture to the theoretical optimum of 3 years can be considered after the effects of the first change are observed.

As a result of the report of the scientific advisers to Panel 5 of the Commission, that Panel will recommend to the Commission at its meeting at St. Andrews in June that a minimum mesh regulation be instituted for International Subarea 5 which includes Georges Bank and the Gulf of Maine. They will recommend a minimum mesh size of 3¾ inches, inside stretched measurement. A mesh of that size retains 50 per cent of the haddock of about 2½ years of age. The Panel is also recommending that intensive research be conducted to assess accurately the effect of the regulation. The Fish and Wildlife Service will conduct this research. The present intensive program which the Service is conducting on the haddock problem will be continued and possibly expanded so that the effect of the regulation can be accurately measured and the whole problem kept under continual review by the Commission.

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PART 3

Mesh Regulation to Increase the Yield Of the Georges Bank Haddock Fishery

By

Herbert W. Graham

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PART 3

Mesh Regulation to Increase the Yield of the Georges Bank Haddock Fishery 1)

By Herbert W. Graham 2)

Introduction. The waste of young haddock caught by the New England otter trawl fleet and the small landings, as compared with landings in certain former years, have been of grave concern to the industry for many years. The United States Government started an intensive study of the haddock fishery in 1931 with the purpose of determining what could be done to improve this important resource. On the basis of these studies recommendations have been made at various times for conservation measures, but no regulations have ever been enacted.

At the first annual meeting of the Commission in Washington in April, 1951, the United States Government presented the haddock problem and proposed that the Commission consider a minimum mesh regulation for Sub-area 5 (Georges Bank and the Gulf of Maine). It was then agreed that it would be desirable to establish a minimum mesh size for haddock fishing in Sub-area 5 as an experiment. It was further agreed that the mesh size should be set at a level which would allow a maximum proportion of unmarketable-sized haddock to escape with minimal effect on the catch of marketable-sized fish. The recommendation was made with the understanding that intensified research would be conducted in order to assess the effects of the regulation.

Biologists from Canada and the United States (the two countries concerned with Sub-area 5) were instructed to study the problem further, especially to determine the exact size of mesh necessary to produce the desired effect. Accordingly, biologists from the Atlantic Biological Station of Canada and the Woods Hole Laboratory of the Fish and Wildlife Service of the United States, constituting the scientific advisors to Panel 5, met three times during the year. All existing data relevant to the problem were studied, new experiments were planned and executed, and the results incorporated into a report to Panel 5 with a specific recommendation.

The Panel 5 scientists recommended 50 percent selection of 40 cm. haddock which on the basis of information then available was believed to be effected with a 3-¾ inch mesh 1). Panel 5 accepted this idea in principle and formalized a detailed recommendation to the Commission. The Commission referred the recommendation to the Standing Committee on Research and Statistics. This Committee approved the recommendation in principle but on the basis of evidence from new mesh experiments recommended a minimum mesh size of 4-½ inches instead of 3-¾ inches (See p. 31). The basis of the conclusions of the scientific group are presented in this report.

Status of the Fishery. Haddock have been the mainstay of the New England offshore fishery for over 25 years and most of these fish have been taken from New England banks. Over two-thirds of the haddock now landed in the United States come from Sub-area 5 (Georges Bank and the western part of the Gulf of Maine). The landings from Georges Bank alone now average about 95 million pounds annually worth about 9 million dollars to the fishermen.

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1) Prepared for the Second Annual Report International Commission for the Northwest Atlantic Fisheries, August 12, 1952.

2) Chief, North Atlantic Fishery Investigations and Director of the Laboratory, Fish and Wildlife Service, Woods Hole, Massachusetts.

1) All mesh sizes referred to in this report are inside dimensions of a used wet net obtained by inserting a flat-wedge-shaped gauge into the mesh under a pressure of 12 pounds.

The Georges Bank haddock fishery was, at certain times in the past, more productive than it is now. (fig. 1). During the early exploitation of this fishery there was one period (from 1927 through 1930) when landings were much higher than they had ever been before or have been since. This was due to the interaction of two factors: a great abundance of fish and intensified fishing. Previous to 1930 there was a relatively high abundance of haddock on the Bank. Although there was a decline in abundance from 1928 to 1930, there was a marked increase in fishing effort during these years, resulting in high landings. From 1930 to 1934 the fishing effort dropped off. This drop in effort was accompanied by a decrease in abundance. The combined effect was a precipitous drop in landings from a high of 223 million pounds in 1929 to a low of 50 million pounds in 1934.

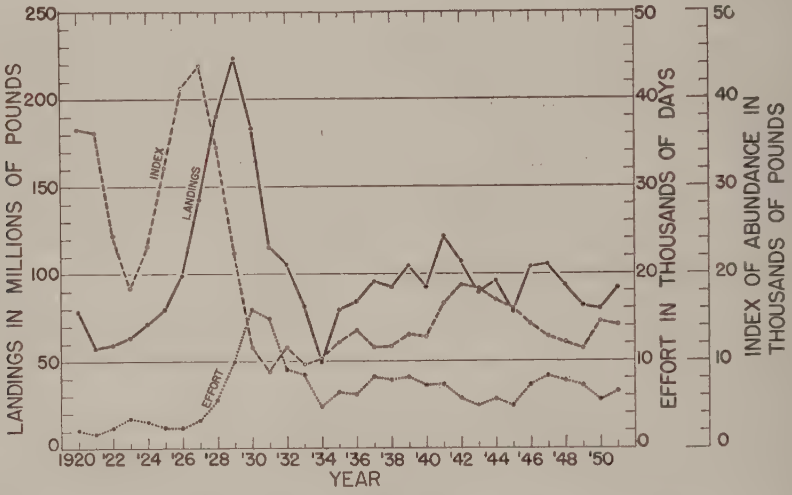

Figure 1. Georges Bank haddock: landings, index of abundance, and fishing effort from 1920 to 1951. The index of abundance is in thousands of pounds of fish landed per day's fishing by a standard trawler.

From 1934 to 1941 there was an upward trend in landings from Georges Bank. During the War years the landings dropped while the abundance of haddock was relatively high. Since the War, landings have fluctuated within the range of landings of the previous ten years. The production from Georges Bank is now, in a sense, stabilized. Fluctuations occur from year to year in accordance with varying strength of year classes passing through the fishery, but for the past ten years the landings have not fallen below 78 million pou nor exceeded 122 million pounds.

A reduction in average size of fish ir population often results from intensive fishi although changes in relative strengths of y classes may obscure any such effect. The aver size of haddock landed from Georges Bank been determined since 1931 (fig. 2). There been no consistent trend upward or downw during this twenty year period. It is worthy note, however, that the average sizes for 1 and 1951 are lower than for any previous y This was caused by the dominance of the 1 year class and may not be related to fisl pressure as the index of abundance during th two years was higher than during the four p ious years (fig. 1).

It is evident that we are concerned wit fishery which has come to an equilibrium w the degree of fishing is determined largely by abundance of fish. When fishing is poor Georges Bank the trawlers move to more dis banks in Sub-area 4. These banks act as a kin buffer for the Georges Bank stock which close to home. Our problem then is not on rehabilitating a depleted stock but rather on increasing the production of an already produc population by proper management practices.

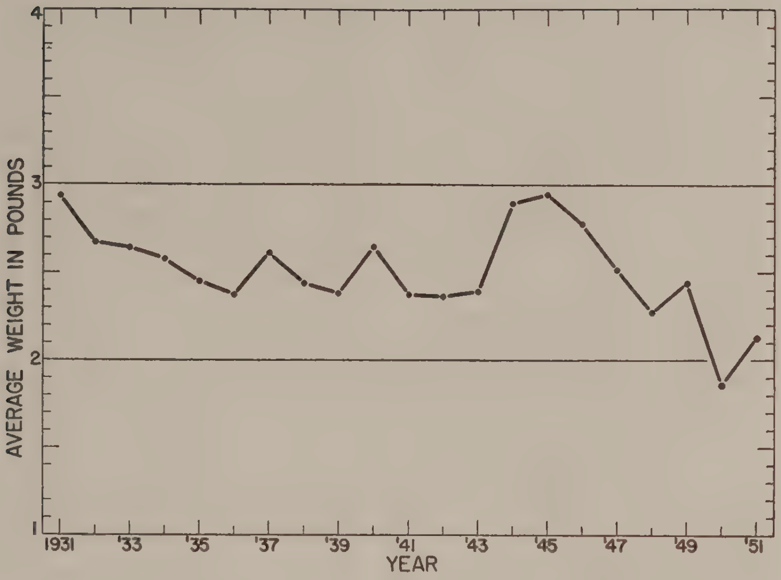

Figure 2. Georges Bank haddock: average weight of fish landed by years from 1931 to 1951.

Discreteness of the stock. The post-larval opulation of haddock on Georges Bank represnts a stock which does not intermingle with ose of neighboring banks. Differences in growth tes and in vertebral numbers, together with mited tagging experiments all indicate that there little, if any, intermigration between the eorges Bank stock and those of other banks. his greatly simplifies the management of this shery as it makes possible the treatment of this ock as an independent unit.

Present fishing practices. At the present me most of the haddock landed from Georges ank are taken by large trawlers fishing out of oston. These vessels use a net which has, in the od end, meshes averaging 2-7/8 inches. Such a et catches large quantities of fish which are too nall for the market. The 50 percent selection oint for this net is 25 cm. This means that of all e fish 25 cm. in length which enter the net, half ill escape and half will be retained; increasing ercentages of smaller fish will be released while creasing percentages of larger fish will be re-ined. The nets now in use retain practically all addock over 30 cm. in length. Such haddock weigh only about 0.6 pounds. The market normally does not accept haddock under 39 cm. (1.3 pounds) and pays a lower price for those under 49 cm. (2.5 pounds) which are graded as scrod haddock. The grading and the acceptable minimum size vary somewhat with the sizes available and the market demand. The fishermen vary their culling accordingly and discard at sea all fish below the size acceptable at the time. Recent studies show that no fish below 27 cm. are retained by the fishermen; 50 percent of the 35 cm. are landed; practically all of the 40 cm. fish; and, of course, all of the fish of larger sizes are landed. (figs. 3 and 4). During one five-year period it was estimated that an average of 15 million pounds were discarded annually. These fish were dead or dying when thrown overboard.

What size to save. It would be difficult to present an argument against the saving of the small fish now killed and discarded at sea. With a stock as intensively fished as the Georges Bank haddock no thinning seems desirable. Therefore even if the natural mortality be high, any fish of sub-marketable size surviving to be caught later at a marketable size would add to the total production.

Although the instructions to the scientific advisers to Panel 5 were to determine the mesh size necessary to save the fish now discarded, the study of this problem naturally led to a consideration of the much broader question of the optimum age of first capture. Can production be increased by advancing the age of first capture beyond the minimum size now accepted by the market?

To answer this it is necessary to take into consideration the growth rates and mortality rates of the stock. It was assumed for purposes of this study that the amount of fishing would remain about the same as during the past ten years. The advisers considered only the question of how to increase the Georges Bank haddock production without altering the present fishing effort.

Growth Rates. The growth rates of Georges Bank haddock are well known through the work of the Woods Hole Laboratory over the past 20 years. (fig. 5). It need only be noted here that the rate of growth of these fish is muc more rapid than that of haddock of neighborin banks or of European waters, especially durin the first 4 years of life which are the years i which the haddock contribute most to the fisher

Mortality Rates. The studies of the lan ings of Georges Bank haddock by the Woo Hole Laboratory over the past 20 years ha yielded valuable information on mortality rate The annual total mortality is calculated to be 4 percent for haddock three years old and olde based on the annual decline in the index abundance of an average year class. (fig. 6 Since haddock are not fully recruited until th are three years old (that is, not all of the fish lesser ages caught are landed) it was not possib to determine the total mortality for haddo under the age of three. For the purposes of the studies it was assumed that the natural mortali was the same as for older fish but during the fi year following age of first capture, it was assum that fishing mortality was one-half that of old

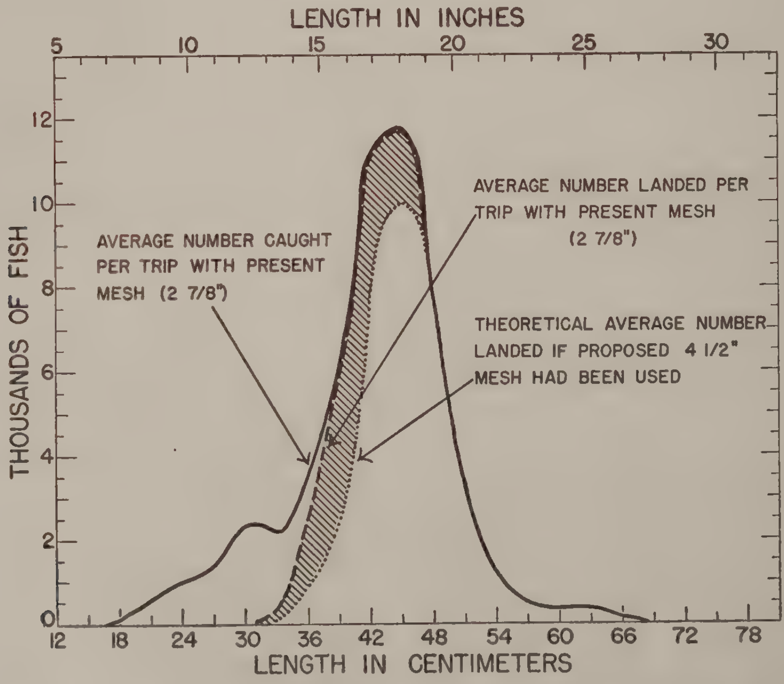

Figure 3. Average length frequencies of haddock caught, and haddock landed during seven observed trips to Georges Bank in 1951 by trawlers using a 2-7/8 inch mesh; and length frequencies of haddock which would have been landed had a 4-1/2 inch mesh been used. The quantity represented by the shaded area represents the initial reduction of landings in numbers of fish.

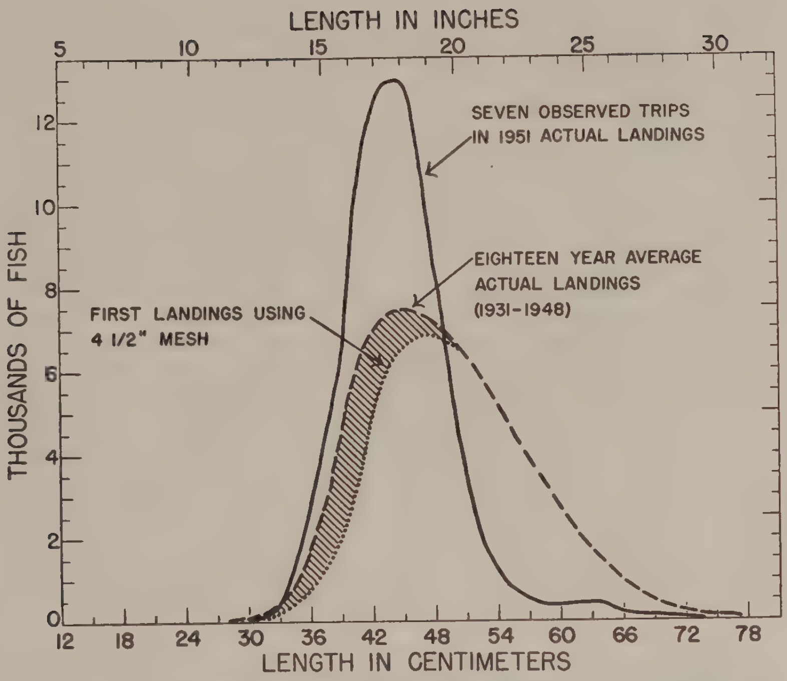

Figure 4. Average length frequencies of haddock landed during an 18-year period (1931-1948) using a 2-7/8 inch mesh, and average length frequency of haddock which would have been landed had a 4-1/2 inch mesh been used on the same population of fish. The quantity rerpesented by the shaded area represents the initial reduction in numbers. The curve of length frequencies obtained from seven observed trips in 1951 is superimposed for comparison with curve of normal distribution.

ges since one-half of the fish of that size escape hrough the meshes.

Total mortality comprises mortality from atural causes plus mortality from fishing. It is esirable to know the natural mortality rates in tudies of this kind but it has not been possible to eparate the natural from the fishing mortality in he case of the Georges Bank haddock. In order o compute the natural mortality it is necessary ither to know the absolute population size or to ave had in the fishery periods of greatly different ishing pressure during the period under study. Neither of these conditions has been satisfied in he case of the Georges Bank haddock so that atural and fishing mortalities have not been eparated. Despite this limitation, an appraisal of he effect of reducing fishing mortalities at the arlier ages has been made.

Optimum Age of First Capture. The relation of yield to the age of first capture for ifferent proportions of natural and fishing ortalities, with a total mortality of 45 percent, is shown in Figure 7. The yield (represented on vertical scale) is in thousands of pounds for each 10,000 fish at age one (end of first year of life). The age (represented on horizontal scale) is that at which the fishery would start catching the fish. The points on the curves represent the total pounds which 10,000 fish at age one would contribute in the course of the life of the year class if the stated natural mortality were alone operative up to the selected age and if the stated ratios of natural and fishing mortalities were together operative from the selected age up to nine years. In specifying the ages of first capture (fig. 7) it has been assumed that nets were used which retained 50 percent of the fish of that age. In other words, it was assumed that one-half the fishing mortality rates apply to the fish present during the first year they are caught. The quantities estimated are those which would be caught after an equilibrium has been established and do not represent the immediate effects which a change in age of first capture may have.

For the purpose of these calculations it was assumed that no haddock live beyond the twelfth year, that is, 100 percent natural mortality was assumed for any haddock remaining after the twelfth year.

Thus we see from Figure 7 that if there were no natural mortality (Curve A) it would pay to allow the haddock to grow to 7 or 8 years of age before catching them. Although there is some growth beyond this age, delaying capture beyond this would result in fewer pounds landed as there would be fewer years in which to apply the fishing pressure. This is admittedly an unrealistic case and is presented only for comparative purposes.

With natural mortality of 7.5 percent and fishing mortality of 37.5 percent (Curve B) the highest yield would be expected if nets were used which retained 50 percent of the 5- or 6-year-old fish.

With natural mortality as high as 30 percent and fishing mortality 15 percent (Curve E) t greatest yield would be expected under conditio of starting capture at age 2. When natur mortality is high it pays to catch the fish early life, otherwise the natural loss of fish outweig the increase in weight of those remaining.

It was the considered opinion of the advise to Panel 5 based on experience in other fisheri that the natural mortality rate does not exceed percent (fig. 7, Curve C). In this case the fishi mortality would be 30 percent. With this co bination of natural and fishing mortalities, t maximum ultimate yield would be expected if t age of first capture were 3 or 4 years. Since t age of first capture is now somewhat under 1- years, it is obvious that considerable benefit cou be expected if it were to be advanced to the a of 3 years.

Let us consider what effect could be e pected from changing the age of first captu

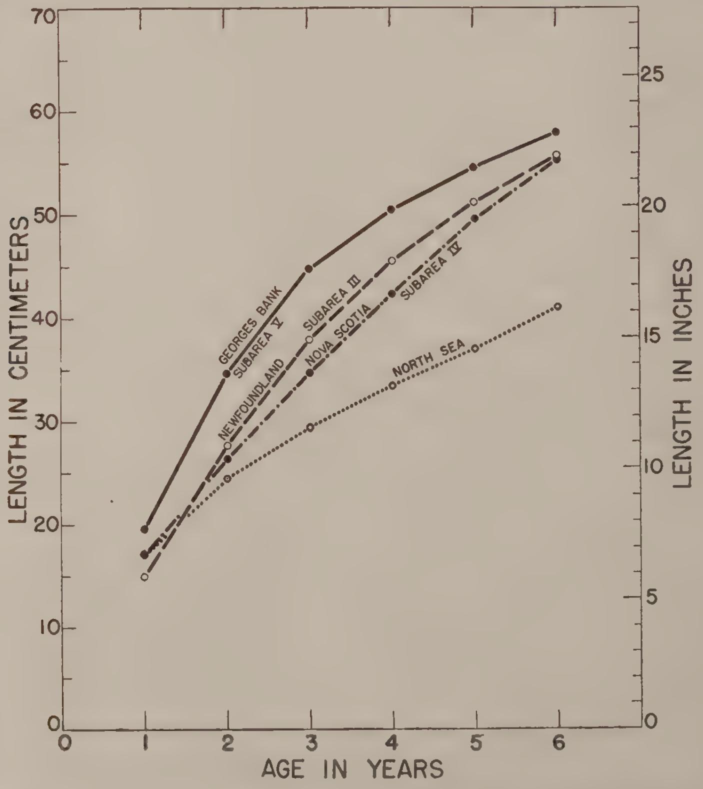

Figure 5. Growth curve for Georges Bank haddock compared with growth curves for haddock from other areas. Georges Bank data from Fish and Wildlife Service unpublished records; other data from Thompson (1939).

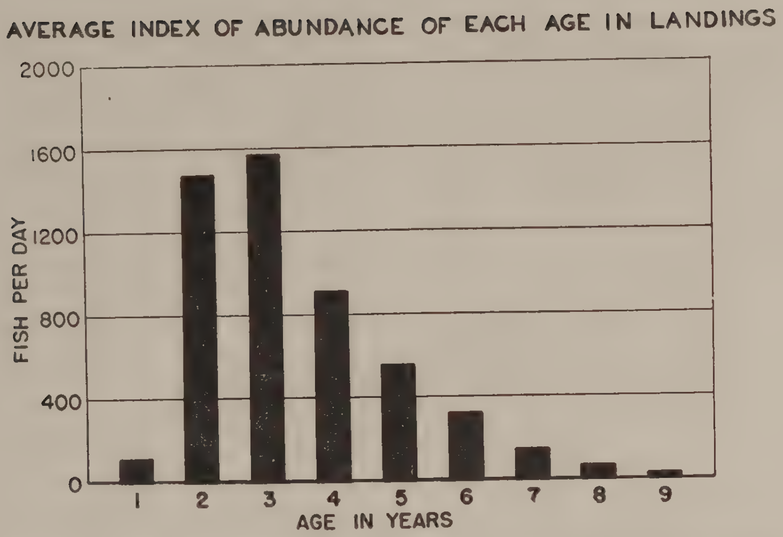

Figure 6. Average index of abundance of each age of Georges Bank haddock as shown by numbers of fish landed per day's fishing. Average of 17 years used. Forty-five percent annual mortality is indicated for fish three years of age and older. Fish under three years of age are not fully recruited.

rom 1-½ to 3 years if the natural mortality were ifferent from the assumed 15 percent. The nalysis presented in Figure 7 shows that if the atural mortality were greater than 15 percent Curves D and E) little difference in yield would e expected whereas if the natural mortality were ess than 15 percent (Curves A and B), much reater benefits would be expected. Thus an dvance in age of first capture to age 3 would not n any case be expected to have any adverse ffect on ultimate yield and might well result in ven greater benefits than those estimated.

Initial Effects. When the age of first cap-ure of population of fish is advanced, by chang-ng fishing practice, there is at first a decrease in ounds caught because of the escape of the small ish formerly captured. If, in the original practice, ll the fish caught had been landed, then the lecreased catch under the new practice would esult in a corresponding decrease in landings. Production would be temporarily reduced until he growth of the protected fish made them avail-ble to the fishermen.

In the case of the Georges Bank haddock ot all the fish now caught are landed. The maller fish are culled and destroyed at sea. Thus he initial effect of advancing the age of first capture would not be so severe as in cases where all fish caught are landed.

It was calculated that advancing the age of first capture from its present one (somewhat under 1-½ years) to the desired 3 years would result in a decrease in landings of about 25 percent the first year, assuming a normal size distribution of haddock that year. If the first year of regulation happened to coincide with a year in which the fishery was being supported by the smaller sizes of fish, the initial decrease in landings would be severe. It was considered inadvisable and unnecessary to risk a large decrease in landings, as the same ultimate effect could be obtained by advancing the age of first capture in two stages.

Accordingly it was decided to recommend advancing the age of first capture in 2 steps so that the initial adverse effects would be minimized and probably have little effect on the fishery. The first step would advance the age of first capture to 2-½ years and the second step would advance it further to 3 years.

The initial effect of the first step on the sizes of fish landed is presented in figures 3 and 4. On seven trips in 1951 during which an observer measured the fish caught, the fish discarded, and the fish landed; practically all the fish under 33 cm. were discarded. (fig. 3). If a 4-½ inch mesh had been used on these trips very few fish of the discarded sizes would have been caught and some of the smaller sizes which were landed would not have been caught. The reduction in pounds landed would have amounted to about 18 percent. This reduction is considerably greater, however, than it would have been during an average year because the average size in 1951 was much lower than in normal years.

The initial effect of change in mesh on sizes landed during an average year is shown in Figure 4. In this case the initial reduction in pounds landed would have amounted to less than 10 percent. The first step, then, can be expected to reduce landings about 10 percent the first year, assuming a normal size distribution of haddock on the banks and assuming normal culling practices. These estimates assume the continuation of fishing intensity at its present level and no appreciable change in fishing efficiency as a result of the use of a larger mesh. Results of experiments conducted elsewhere indicate that the efficiency of the trawls may be increased. In this case the
initial effect of a change in mesh on landin
might be considerably less than that calculated

During the second year of regulation the fi
released in the preceding season should so i
crease the abundance of haddock as to bring t
landings back to normal. During the third ye
the increased abundance resulting from the
lease of young in two seasons should result
catches 10 to 15 percent above normal. In s
ceeding years the benefits would increase until
new equilibrium will have been established w
landings about 30 percent greater than bef
regulation.

If the second step were then taken, anot
decline in landings would be expected the fi
year, but a new equilibrium would be establish
at a higher level than under the first step.

The advisers to Panel 5 have recommend
taking the first step of advancing the age of fi
capture from the present one (somewhat un
1-½ years) to the desired 2-½ years and
panding research in order to test the effectiven
of the new practice.

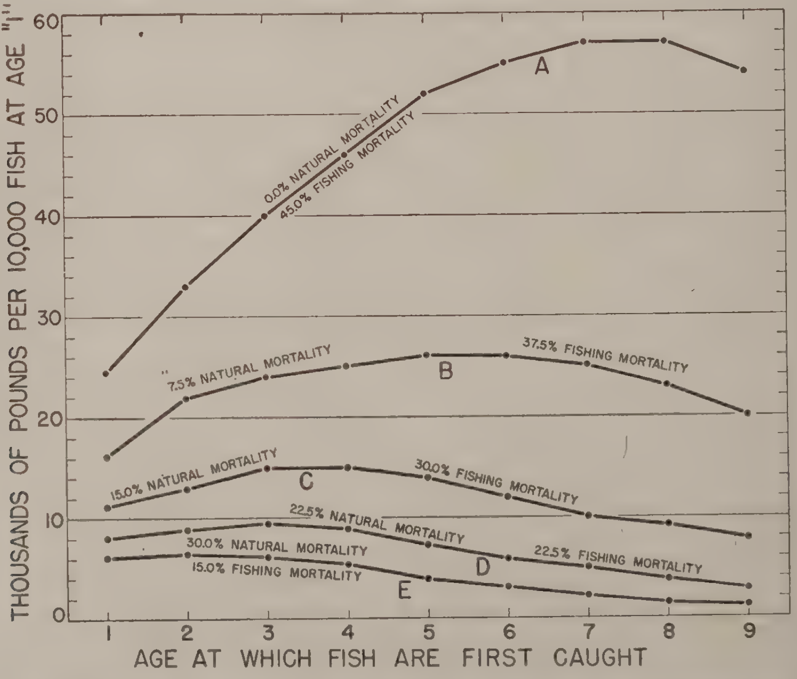

Figure 7. Relation of yield to age of first capture for various proportions of natural and fishing mortalities. See text for explanation.

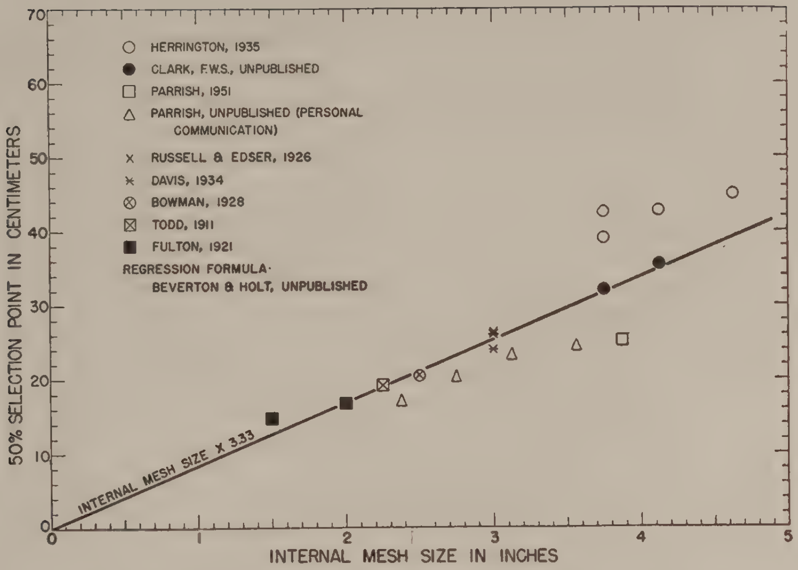

Figure 8. Relation of size of mesh to size of haddock retained. The results of Clark (solid circles) were obtained from the experiments conducted on board the Michigan.

Necessary Mesh Size. Haddock 2-½ years age average about 40 cm. (16 inches) in ngth and weigh about 1.4 pounds. In order to tablish 2-½ years as the age of first capture it is ecessary that the fleet use nets having a 50 per- nt selection point at 40 cm.

Determining the exact size of mesh to effect 50 percent selection at 40 cm. has been diffi- ilt. The results of various experiments by uropean and American scientists have not been complete agreement. These are presented in igure 8.

The advisers to Panel 5 recommended a esh size of 3-¾ inches. This was based on the ıen best available information. Clark's experi- ents on the *Michigan* were conducted after the anel 5 recommendation was made. A study of e results of Clark's experiments showed them be most nearly valid and most applicable to the opulations of haddock on Georges Bank. These cperiments showed that a much larger mesh than -¾ inches would be required to effect a 50 per- nt selection of 40 cm. fish. A mesh of 4-½ ches was indicated as the necessary size and it as on the basis of these experiments that the ommittee on Research and Statistics recom- ended to the Commission rewording of the Panel recommendation so that it read 4-½ inches rather than 3-¾ inches.

Measuring the Effect of the Regulation. Since landings fluctuate so much due to natural fluctuations in abundance, it will not be possible to assess the effect of the regulation by a direct comparison of landings before and after regulation except on a long-term basis, comparing, say, the next ten years' landings with those of the ten years before regulation. It should not be necessary, however, to wait ten years to obtain a measure of the effect of the regulation.

First, a comparison of the numbers, sizes, and ages of haddock discarded at sea before and after regulation will be made. This study will provide a measure of the effectiveness of the new gear in releasing unmarketable fish but will not provide information on the effect the saving of young fish has on actual landings.

The principal test of the effectiveness of the regulation will be a comparison of the total yields from individual year classes of known initial strengths. If the regulation accomplishes its purpose, a year class of a given strength at, say, two years of age, will contribute more to the landings throughout its life time than would have a year class of the same initial strength before regulation.

Testing the effectiveness of the regulation requires an accurate measure of year class strengths at early ages. At the present time the Woods Hole Laboratory is maintaining indices of abundance of all year classes from age two, expressed as pounds landed per day per standard vessel. The index is relative only, and is based on present fishing practices with present nets which have an average inside dimension of 2-⅞ inches. Since the two-year-old haddock are not fully recruited with this gear (not all are retained by this size of mesh), the present index for 2-year-olds is not directly comparable to that of older fish, which are fully recruited. The index for 2-year-olds, however, is as accurate as that for older fish for comparisons between years, as long as the same size of mesh is used by the fleet studied. If the size of mesh is increased, of course, we no longer have a comparable index for the 2-year-olds.

For this reason it is essential that some vessels be licensed to fish with the present size of mesh in order to obtain an index for the incoming 2-year-olds comparable to that of former years. Accordingly, the Commission has recommended that the United States Governmen license up to eight trawlers to use the old-size mesh so that the required index can be obtaine

With the ratio of 2-year-olds to older ag groups available from this group of vessels, th relative strengths of incoming year classes can b established. It will then be possible to evaluate th effect of the change in mesh by comparing th yields of year classes of comparable strength under the old fishing practice and the new.

This test rules out normal fluctuations i year class strengths as a factor affecting yield bu in order to measure the effectiveness of th regulation we must distinguish such effects fro the effects of changing natural condition Fluctuations in abundance may occur due t changes in growth rates or natural mortality rat brought about by natural conditions. Any chang in growth rate can be readily measured but a ne natural mortality would not be easily recognize This difficulty should be circumvented if the pr posal of Panel 5 scientists to make a secon change in mesh size is realized. The value of th measure of the effect of the regulation will improve if the second change in mesh size is broug about.

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FURTHER STUDIES ON THE NUTRITION OF *HEMOPHILUS PISCIUM*[*]

PHILIP J. GRIFFIN[†]

Hemophilus piscium is the etiological agent of "ulcer disease," an infection prevalent in certain salmonoid fishes.[19] Recent studies have indicated that diphosphothiamine (cocarboxylase) or adenosine triphosphate (ATP), but not hemin (X factor) and/or coenzyme I (V factor), could replace blood or other natural materials as supplements for the growth of this micro-organism.[6] The present report is concerned with the effect of a number of related compounds on the growth of *H. piscium* and with the development of a synthetic medium which supports the growth of this bacterium.

METHODS

Several strains of *H. piscium* were grown at 22° C. for 48 hours on nutrient agar supplemented with 10 per cent sterile defibrinated rabbit blood. A loopful of the resulting growth was emulsified in 10 ml. of the basal medium which contained proteose-peptone #3 (Difco) plus glucose[6] and incubated for 24 hours at 22° C.; visible growth was present at this time. One-tenth ml. of this culture was inoculated into 10 ml. of the fresh sterile basal medium and again incubated for 24 hours at 22° C. A faint growth response was evident at the end of this interval. The culture was then centrifuged at 2,000 r.p.m. for 10 minutes, the supernatant removed, and the organisms resuspended in 10 ml. of sterile basal medium. This process of sedimenting the organisms, removing the supernatant, and resuspending the bacteria was repeated twice. The organisms were finally suspended in 10 ml. of sterile basal medium and then diluted 1:5 with 0.9 per cent saline. One drop delivered from a 1 ml. pipette served as the inoculum for the various tests to be described. In this manner the transfer of accessory growth substances from the original blood-enriched medium was usually eliminated.

Materials to be tested for growth-promoting activity were sterilized by passage through Chamberland or Selas filters. Suitable controls were included to test the sterility of the added substances. After incubation for 96 hours at 22° C., growth was recorded in terms of optical density (Klett-Summerson photoelectric colorimeter; 660 mμ. filter).

RESULTS

Stimulatory effect of hemin. It has been shown that cocarboxylase or ATP are highly active in replacing such natural materials as blood or fish peptone in the growth of *H. piscium*.[6] However, the growth response to

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cocarboxylase or ATP approached, but never equaled, the growth which resulted in the basal medium containing either of these natural products. An absolute requirement for hemin had been ruled out in previous studies.[19] However, recent observations indicate that the addition of hemin to the basal medium containing either cocarboxylase or ATP produces a marked increase in the growth of *H. piscium*. The greatest stimulation occurred with 8-10 μg. of hemin per ml. of the basal medium. Frequently, the amount of growth was double that which was obtained with either cocarboxylase or ATP alone, and usually equaled the growth response to blood or fish peptone. Thus most, perhaps all, of the special activity of the natural products may be attributed to these substances.

Activity of thiamine and thiamine monophosphate. Since thiamine in concentrations as high as 100 mg. per cent did not support the growth of *H. piscium,* it appeared to be of interest to investigate the effect of thiamine in combination with either ATP or cocarboxylase. Cocarboxylase* was employed in a concentration of 10 μg. per ml. of basal medium, and varying concentrations of thiamine were added in a range of from 1 to 1000 μg. per ml. Similar tests were performed substituting ATP for cocarboxylase at a level of 50 μg. per ml. of basal medium. Although there were some slight differences encountered with the various strains of *H. piscium* employed, the data indicated that approximately 1000 μg. of thiamine per ml. of basal medium will inhibit practically all of the growth of *H. piscium* which normally occurred when 10 μg. per ml. of cocarboxylase were added to the basal medium. In the presence of ATP, inhibition of the growth of *H. piscium* was noted at slightly lower levels of thiamine. In other tests employing thiamine at a level of 1000 μg. per ml. of basal medium, the inhibition of growth could be overcome by progressively increasing the concentration of either cocarboxylase or ATP above 10 or 50 μg. per ml. respectively. Preliminary studies of the thiamine-cocarboxylase system suggest that the inhibition is competitive.

Thiamine monophosphate† in a concentration of 40 μg. per ml. of basal medium was tested for its ability to support the growth of *H. piscium*. This substance also supported the growth of the micro-organism and was found to be approximately 80 per cent as active as cocarboxylase. Pyridoxal phosphate,‡ employed at a concentration of 5 μg. per ml. of basal medium and glucose-1-phosphate, fructose-6-phosphate, and hexose diphosphate used in concentrations of 50 μg. per ml. of basal medium, respectively, proved to be devoid of growth-promoting activity for *H. piscium*.

Effect of adenylic acid and adenosine diphosphate. Adenylic acid¶ was dissolved in M/50 KH_2PO_4, sterilized by filtration, and used in a concentration of 40 μg. per ml. of basal medium. The barium salt of adenosine diphosphate* (ADP) was converted to the sodium salt by dissolving the material in cold distilled water by the addition of 5N HCl, precipitating the barium as $BaSO_4$ with 1M Na_2SO_4, neutralizing as rapidly as possible with 5N NaOH, and filtering through No. 5 Whatman filter paper. The material was then diluted with distilled water, sterilized by filtration, and employed in the basal medium at a concentration of 40 μg. per ml. (calculated as the sodium salt). In the concentrations employed, these substances supported the growth of *H. piscium* but were not as active in this respect as 2 μg. of cocarboxylase per ml. of basal medium. If the optical density reading recorded for the growth response to 2 μg. of cocarboxylase per ml. of basal medium is arbitrarily assigned a value of 100 per cent, then the response of *H. piscium* to 40 μg. of adenylic acid per ml. of basal medium was approximately 15 per cent and the response to 40 μg. of ADP per ml. of basal medium was approximately 43 per cent. ATP in a concentration of 40 μg. per ml. of basal medium produced a response in the growth of *H. piscium* which was approximately 90 per cent of that occurring in the presence of 2 μg. of cocarboxylase per ml. of basal medium.

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* Kindly supplied by Merck and Co., Rahway, New Jersey.

† Obtained from Dr. J. Melnick, Yale University.

‡ Provided by Dr. W. Umbreit, Merck Institute for Therapeutic Research, Rahway, New Jersey.

¶ Delta Chemical Works, New York; also Sigma Chemical Co., St. Louis, Missouri.

It should be noted that 1 to 2 μg. of cocarboxylase per ml. of basal medium were more active than any of the adenine compounds tested. An increase in the concentration of cocarboxylase above these levels did not result in any appreciable increase in growth.

Although slight strain differences apparently exist, an increase in the concentration of ATP or ADP above 20 and 40 μg. per ml. of basal medium, respectively, did not result in an increased growth response. The data concerning the growth of *H. piscium* in the presence of adenylic acid must be interpreted with caution since in about half of the tests no growth occurred, and in the remaining tests the growth response was weak.

Microbiological assay of adenylic acid, ADP and ATP for contamination with thiamine. In a previous report[6] it was suggested that the activity of ATP might be attributed to the presence of small amounts of cocarboxylase present as a contaminant. This possibility was tested by the application of a microbiological assay for thiamine to the various adenine compounds employed in this study. In the assay procedure, *Lactobacillus fermenti* served as the test organism.[18] Dr. H. P. Sarett of the School of Medicine, Tulane University, New Orleans, Louisiana, kindly performed the thiamine assays.

ATP was tested at levels of from 1.0 to 250 μg. per 10 ml. of medium per tube. The values obtained from several experiments in which 50 to 250 μg. of ATP were employed produced a growth response of *L. fermenti* which was duplicated with from 0.015 to 0.02 μg. of thiamine. The best representative value appeared to be 0.018 μg. of thiamine per 100 μg. of ATP. ADP had very slight activity for *L. fermenti,* and the growth was not linearly proportional to the concentration of ADP. From 50 to 500 μg. of ADP per tube produced a growth response equivalent to that obtained with 0.002 to 0.005 μg. of thiamine. The assay of adenylic acid indicated that this material supplied essentially no thiamine when used at levels of from 50 to 500 μg. per 10 ml. of medium per tube. A few tubes occasionally gave slight turbidimetric readings, but these were not constant enough to permit any definite conclusion. The tubes showing growth were usually those with the intermediate amounts of adenylic acid and not those with the highest concentrations.

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* Sigma Chemical Co., St. Louis, Missouri.

Adenylic acid, ADP, and ATP were tested in amounts of 10 and 50 μg. per tube in the presence of 0.01 and 0.03 μg. of thiamine to determine whether they stimulated the growth of the assay organism, *L. fermenti.* In all cases the growth with thiamine plus any of the adenylic compounds appeared to be additive, subject to the qualifications above.

The smallest concentration of ATP necessary to support the growth of *H. piscium* was 2.0 μg. per ml. of basal medium. If one assumed, on the basis of the thiamine assay of ATP with *L. fermenti,* that all of the thiamine was present in ATP as cocarboxylase, then the total amount of cocarboxylase present in 2 μg. per ml. of ATP necessary to initiate growth was approximately 0.0004 μg. per ml. Assays of cocarboxylase with *H. piscium* indicated that the amount required to initiate growth with the most sensitive strain (XI) was 0.003 μg. per ml. The difference in the required levels was also evident with the other test strains of *H. piscium* employed. Further assays utilizing the strain of *H. piscium* (XX) most sensitive to ADP have shown that 8.0 μg. of ADP or 0.05 μg. of cocarboxylase per ml. were necessary to initiate growth. On the basis of the thiamine assay of ADP with *L. fermenti,* if one assumes that 8.0 μg. of ADP per ml. of basal medium contained as much as 0.005 μg. of cocarboxylase, then it is apparent that this level also lies below the sensitivity of this strain of *H. piscium* to cocarboxylase. Therefore, it appears reasonable to conclude that the activity of ATP or ADP in supporting the growth of *H. piscium* is not due to contamination with cocarboxylase.

Growth of H. piscium in a synthetic medium. A semi-synthetic basal medium capable of supporting the growth of *H. piscium* was developed (Table 1). This medium contained several of the salts and vitamins required by many heterotrophic organisms which have been grown in defined media by other investigators. Good growth of strains XI and XIII of *H. piscium* occurred in this medium in 24 hours in the presence of added cocarboxylase. Strains XVIII and XX of *H. piscium,* however, required the addition of 0.05 ml. of an alkaline hydrolyzed yeast nucleic acid (Pfanstiehl). At least ten successive subcultures of all strains of *H. piscium* were made in this medium employing one loopful of the culture for each transfer.

Excellent growth also resulted when the above medium was further modified by employing a combination of 46 chemically defined compounds which included various amino acids, adenine, guanine, uracil, hemin, vitamins (including cocarboxylase), glucose, and mineral salts. All strains of *H. piscium* grew well and were transferred through at least 15 subcultures. The necessity of employing acid hydrolyzed casein and yeast nucleic acid was thus eliminated.[7]

TABLE 1

COMPOSITION OF A SEMI-SYNTHETIC MEDIUM FOR *H. piscium*

"Vitamin free" acid hydrolyzed casein	5.0 g.	Glucose	5.0 g.
L-cystine	0.1 g.	Ca. pantothenate	1.0 mg.
DL-Tryptophan	0.05 g.	Nicotinamide	0.5 mg.
DL-Serine	0.01 g.	Biotin	2.0 μg.
K_2HPO_4	0.25 g.	$MgSO_4 \cdot 7H_2O$	200 mg.
KH_2PO_4	0.25 g.	$MnSO_4$ (anhydrous)	1.0 mg.
NaCl	5.0 g.	$FeSO_4 \cdot 7H_2O$	20.0 mg.

Distilled water to 1000 ml.
pH 7.2 adjusted with 1N NaOH, then autoclaved at 121° C. for 10 minutes.
Cocarboxylase was added at a level of 2.0 μg. per ml. basal medium prior to inoculation.

DISCUSSION

The importance of supplementing a medium with either a prephosphorylated metabolite or a suitable transphosphorylating agent has been suggested by the work of many investigators,[12, 16, 20, 21] and strong evidence exists for the view that the phosphate derivatives of many of the vitamins, rather than the free forms, are active in metabolism. This applies clearly to thiamine in certain bacteria, for Lipmann[13] found that cocarboxylase rather than free thiamine mediated the oxidation of pyruvic acid. Barron and Lyman[1] reported that thiamine was inactive and cocarboxylase active in the oxidation of pyruvate by gonococci and hemolytic streptococci. Lohmann and Schuster[15] obtained similar data with yeast cells. It appears probable that thiamine is the precursor of cocarboxylase.[17] Some confirmation of this viewpoint comes from the demonstration of enzymes capable of phosphorylating thiamine which are present in a variety of cells. The available data indicate that adenosine triphosphate is probably the usual phosphorylating agent.[8, 14, 22]

The behavior of *H. piscium* may exemplify the profound enhancement in biological activity achieved by phosphorylating the vitamin moiety, since thiamine, in concentrations up to 100 mg. per cent did not support growth. In contrast with this finding, the phosphorylated derivative, diphosphothiamine, showed maximal activity in concentrations of 1 to 2 μg. per ml.

If the requirement for an exogenous supply of a growth factor reflects an impairment in synthesis, then the question arises as to the nature of the defect in the metabolism of *H. piscium*. The inactivity of thiamine and the activity of cocarboxylase may imply that the bacterium cannot convert thiamine to diphosphothiamine. However, thiamine monophosphate was highly active in promoting growth. Green and his associates[5] indicated that thiamine monophosphate could not replace the diphosphate in reactivating a carboxylase preparation, and Weil-Malherbe[22] reported that the monophosphate was inactive as the coenzyme of carboxylase from yeast. Therefore, if the diphosphate is the only compound possessing immediate cocarboxylase activity and if cocarboxylase is the compound of central importance in the metabolism of *H. piscium*, it may be reasonable to suggest that the response to the monophosphate is a reflection of its conversion to the diphosphate. It would then appear that the defect centers about the mechanism concerned with the initial phosphorylation of thiamine. The activity of the various adenine derivatives in a basal medium deficient only in diphosphothiamine poses the next question. If adenosine triphosphate is indeed the phosphorylating agent involved in the conversion of thiamine to diphosphothiamine, the activity of the adenine compounds in supporting the growth of *H. piscium* may be understandable. Lack of growth in an unenriched medium may be a result of the inability of the organism to synthesize certain substances, such as ATP, at a rate sufficient to satisfy the demands of the organism. The fact that adenylic acid would occasionally elicit a weak growth response might indicate that the organism still retains the ability to perform a limited amount of synthesis of ATP when given a suitable point of departure. This possibility parallels the suggestion that many highly specialized parasites are difficult to culture on artificial media due to their inability to synthesize an energy source such as ATP.[3, 11, 21]

Another suggestion may be advanced, based on the observation that thiamine will inhibit the growth of *H. piscium* in the presence of either diphosphothiamine or ATP. The organism may synthesize thiamine (or some other substance) so abundantly that a metabolic imbalance results. One might then assume that a high ratio of thiamine synthesis to cocarboxylase synthesis leads to a situation which is analogous to the *in vitro* demonstration of the inhibition of growth by an excess of thiamine. The addition of either an excess of a phosphorylating agent such as ATP, a suitable nucleus for synthesis such as adenylic acid or ADP, or a compound whose function may be directly interfered with in the competition, such as diphosphothiamine or thiamine monophosphate, may correct this imbalance.

With the notable exception of the work on *Hemophilus parainfluenzae* by Herbst[8, 9] and Herbst and Snell,[10] it appears that the growth requirements of various members of the genus *Hemophilus* have been investigated only in terms of the X and V factors. This is unfortunate and unnecessarily restrictive. Investigations such as those of Gingrich and Schlenk,[4] who have demonstrated that the requirement for coenzyme I by so typical a member of the genus as *Hemophilus influenzae* is not absolute, suggest that nutritional studies of hemophilic bacteria be extended to include the utilization of various phosphorylated intermediates.

SUMMARY

Although *H. piscium* lacks an absolute requirement for hemin, this compound in the presence of cocarboxylase or adenosine triphosphate produced a growth response which equaled that obtained with blood or fish peptone.

Adenosine diphosphate and thiamine monophosphate were found to support the growth of *H. piscium*. Equivocal growth occurred in the presence of adenylic acid.

The results of microbiological assays for thiamine in the various phosphorylated adenine compounds employed suggest that the activity of these compounds is not due to contamination with cocarboxylase.

Thiamine proved inhibitory to the growth of *H. piscium*. In separate tests it was found that this inhibition could be reversed by increasing the concentration of either cocarboxylase or ATP above those levels at which the inhibition occurred. Preliminary studies of the thiamine-cocarboxylase system indicate that the inhibition is probably competitive.

The organism was grown and subcultured repeatedly in a defined medium which contained various amino acids, adenine, guanine, uracil, glucose, hemin, several of the vitamins (including cocarboxylase), and mineral salts.

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VARIATIONS IN THE FEEDING HABITS OF THE STRIPED BASS, *ROCCUS SAXATILIS* (WALBAUM), IN CHESAPEAKE BAY[1]

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ABSTRACT

The stomachs of 1,736 striped bass, *Roccus saxatilis* (Walbaum), from Chesapeake Bay, taken from June 1936 to April 1937, were examined for contents. The most

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[1] This report is based in part on a thesis submitted by the author to the Graduate School, University of Maryland, May 1937, in partial fulfillment of the requirements for the degree of Master of Science.

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common foods present were anchovy (*Anchoa mitchilli*) and menhaden (*Brevoortia tyrannus*), but young spot (*Leiostomus xanthurus*) and croaker (*Micropogon undulatus*) were prominent foods also. Crustaceans were secondary to fishes as food items both in number and weight. A distinct seasonal and regional variation in food composition was found. Anchovy and menhaden, dominant forms in summer and fall, were replaced by spot and croaker in the winter. White perch (*Morone americana*) and herrings (*Pomolobus*) were common in spring and early summer. Fresh-water organisms were dominant in samples taken from the Head of Chesapeake Bay. There was a tendency toward reduction of feeding in late May and early June, a period corresponding to the spawning season.

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INTRODUCTION

As a part of the investigations of the life history of the rock or striped bass, *Roccus saxatilis* (Walbaum), in Chesapeake Bay waters from 1936 to 1938, the contents of 1,736 stomachs were examined to determine the percentage that contained food and the kinds of organisms eaten by season and by locality. Although striped bass are reputed to be voracious feeders, published information on their food is scant.

Hildebrand and Schroeder (1928) examined the stomachs from 48 striped bass from Chesapeake Bay and LeCompte (1926) and Haddaway (1930) published popular accounts in which they mentioned its feeding behavior in Chesapeake Bay waters. The food of this species has been discussed briefly by Bigelow and Welsh (1924: 255) for the Gulf of Maine, by Smith (1907: 273) for North Carolina waters, and by Verrill (1873: 514), who reported on a few stomachs examined at Great Egg Harbor, New Jersey and at Woods Hole, Massachusetts. Merriman (1937: 32–33) reported on his examination of about 250 stomachs, most of which were from Con-

TABLE I. DATA ON THE NUMBER AND PER CENT OF STRIPED BASS STOMACHS WHICH CONTAINED FOOD

Date	*Locality*	*Fishing Gear*	*Number Examined*	*Number*		*Per Cent*	
				Full	*Empty*	*Full*	*Empty*
VI/1 to IX/30, 1936*	Head of Chesapeake Bay	Mainly hook and line	263	175	88	66.5	33.5
VII/21–22, 1936	Rock Hall, Maryland	Pound nets	420	152	268	36.2	63.8
IX/10 to XI/11, 1936	Rock Hall, Maryland	Hook and line; pound nets	100	43	57	43.0	57.0
XII/4–28, 1936	Vicinity, Rock Hall, Md.	Gill nets	124	54	70	43.6	56.4
X/25–29, 1936	Tilghman Island, Md.	Hook and line; pound nets	18	8	10	44.4	55.6
II/10, 1937	Tilghman Island, Md.	Gill nets	124	107	17	86.3	13.7
III/18–19, 1937	Tilghman Island, Md.	Haul seine	6	3	3	50.0	50.0
I/4–18, 1937	Hooper Island	Gill nets	148	110	38	74.3	25.7
VIII/21–25, 1936	Galesville, Maryland	Pound nets	205	112	93	54.6	45.4
X/8 to XI/12, 1936	Galesville, Maryland	Pound nets	7	5	2	71.4	28.6
VI/20 to VIII/18, 1936	Solomons Island, Md.	Hook and line	135	64	71	47.4	52.6
IX/16 to X/6, 1936**	Solomons Island, Md.	Hook and line	60	39	21	65.0	35.0
X/6, 1936	Potomac River near Colonial Beach, Va.	Pound nets	4	4	0	100.0	0
III/12, 1937	Potomac River, Virginia	Gill nets	2	2	0	100.0	0
XII/3/1936–I/22/1937	James River, Virginia	Fyke nets	74	53	21	71.6	28.4
III/20, 1937	James River, Virginia	Fyke nets	45	37	8	82.2	17.8
		Total	1735	968	767	55.8	44.2

* One group of 79 stomachs, of which 56 contained food, were collected from anglers during August and September and preserved in a single container. Exact dates were not available.

** One stomach was examined from Solomons April 22, 1937. It was from an 11-pound female, 725 mm long. The contents were 3 menhaden, 2 glut herring, 1 branch herring, and 2 isopods, totaling 473 g.

necticut waters. On the Pacific Coast, where this species was introduced, Scofield and Bryant (1926: 66–67), Scofield (1928: 37; 1931: 56–57) and Shapovalov (1936) have noted its feeding behavior. Most of the literature indicates that fishes constitute the dominant food for striped bass.

The stomachs examined in this study were obtained from fish used by Vladykov and Wallace for morphometric studies, the fish having been obtained from both commercial and sports fisheries. Immediately upon capture, or as soon thereafter as possible, the stomachs were removed and preserved in individual bottles containing about 4% formalin solution. Data on size, weight, sex, and stage of maturity were recorded for each sample. A summary of the collections is given in Table I.

TABLE II. List of Fish Species Found in the Stomachs of Striped Bass Caught During the Period 1936–1937 in Chesapeake Bay

Common Name	*Scientific Name*	*Conowingo*	*Rock Hall*	*Tilghman Is.*	*Hooper Is.*	*Galesville*	*Solomons Is.*	*Potomac R., Va.*	*James R., Va.*
Anchovy	*Anchoa mitchilli*	—	×	×	—	×	×	—	×
Bullhead	*Ameiurus* sp.	×	—	—	—	—	—	—	—
Butterfish	*Poronotus triacanthus*	—	—	—	—	×	—	—	—
Crappie	*Pomoxis* sp.	×	—	—	—	—	—	—	—
Croaker	*Micropogon undulatus*	—	×	×	×	—	×	—	×
Dace, Blacknose	*Rhinichthys atratulus*	×	—	—	—	—	—	—	—
Eel	*Anguilla rostrata*	×	—	—	—	—	×	—	—
Flounder	*Etropus crossotus*	—	—	—	×	—	—	—	—
Goby	*Gobidae*	—	—	—	—	—	×	—	—
Gray trout	*Cynoscion regalis*	—	×	—	—	—	×	—	—
Herring, Branch	*Pomolobus pseudoharengus*	—	×	×	—	—	×	×	×
Glut	*Pomolobus aestivalis*	—	—	×	—	—	×	—	×
Menhaden	*Brevoortia tyrannus*	—	×	×	×	×	×	×	×
Mud Shad	*Dorosoma cepedianum*	—	—	—	—	—	—	×	×
Red drum	*Sciaenops ocellatus*	—	—	—	—	—	—	—	×
Shad	*Alosa sapidissima*	—	×	—	—	—	—	—	×
Silversides									
Common	*Menidia menidia*	—	×	—	—	×	—	—	×
Rough	*Membras vagrans*	—	×	—	—	—	×	—	—
Spot	*Leiostomus xanthurus*	—	×	×	×	×	×	—	×
Spot-tail Shiner	*Notropis hudsonius*	×	—	—	—	—	—	—	—
Ten pounder	*Elops saurus*	—	—	—	—	—	—	—	×
White perch	*Morone americana*	—	×	×	—	—	—	×	×
Yellow perch	*Perca flavescens*	×	—	—	—	—	—	—	—

ANALYSES OF STOMACH CONTENTS

First the stomachs were classified as either "full" or "empty," a stomach containing any material whatsoever being called full. In samples taken with hook and line, no distinction was made between a stomach containing bait and one with natural food, since the fish was feeding in either case. In the laboratory, each stomach was split and all of the contained material was washed into a glass dish; this material was then examined with a low power binocular dissecting microscope. Food organisms were separated, identified, counted, and weighed, and lengths of ingested fish were measured or estimated on the basis of undigested fragments. Of the 1,73 stomachs which were obtained for analysis, 969 contained food an the data acquired from these observations are summarized in Tables I to VII.

Frequencies of food types were obtained by counting all stomachs that contained the same types of food regardless of the quantities of individual organisms. Thus a stomach containing a single organism and a stomach containing many of the same organism were given the same tally inasmuch as each of them possessed the same type of food. Since some stomachs contained more than one food species, the total number of occurrences of food organisms was higher than the number of full stomachs present in many samples.

Fishes, because they constituted the predominant food group, received special attention and were identified to species whenever possible. Table II presents the common and scientific names of the species found in the striped bass stomachs by localities, and to avoid repetition, only the common names will be used in subsequent parts of this paper. The identification of partially digested fish was determined by means of otoliths, scales, structure of distinctive bones, number and type of gill rakers, and other known characters that were checked against a reference collection. In some instances the shape, size, and color of the stomach and other viscera of the ingested fish served as means of identification. The invertebrate groups were identified to orders.

FOOD GROUPS

Fish. The total weight of food in 969 full stomachs was at least 8,945 g, or about 20 pounds. Of this weight, fish comprised about 95%.

The occurrence of forage fishes (32.9%) was lowest in the stomach samples taken from the Head of Chesapeake Bay (Table III). This was in sharp contrast with all other samples, where the occurrence of fishes was much higher, ranging from 46.2 to 100% in some of the smaller samples. The most important forage fishes were the anchovy, menhaden, spot, and croaker. Frequently one species constituted the principal food, but in many instances individual bass fed on several species. One striped bass taken on September 10, 1936 at Rock Hall, Maryland had in its stomach 26 anchovies and four herrings that weighed a total of 59 g. Even more diversified was the food found in a bass from the James River, Virginia, taken on March 29, 1937; this fish, 363 mm long, had eaten 55 anchovies, one menhaden, and three herrings, giving a total weight of 54 g.

Crustaceans. Crustaceans were of secondary importance as food, their percentage of occurrence varying from 0 to 46.3 (Table III). By weight, they amounted to less than 2% of all food examined.

TABLE III. FOOD ITEMS AND THEIR FREQUENCY OF OCCURRENCE IN NUMBERS AND PER CENT IN STRIPED BASS STOMACHS BY SEASON AND REGION

	SUMMER				FALL					WINTER				SPRING		
Food Items	*Head of Chesapeake Bay*	*Rock Hall, Md.*	*Galesville, Md.*	*Solomons, Md.*	*Rock Hall, Md.*	*Tilghman, Md.*	*Galesville, Md.*	*Solomons, Md.*	*Potomac River near Colonial Beach, Va.*	*Rock Hall, Md.*	*Tilghman, Md.*	*Hooper, Md.*	*James River, Va.*	*Tilghman, Md.*	*Potomac River, Va.*	*James River, Va.*
	Number															
Fishes	81	151	105	52	43	8	5	25	4	53	107	98	44	3	2	37
Copepods	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—
Cladocerans	61	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Isopods	—	—	8	12	2	—	1	10	—	3	2	—	5	—	—	2
Mysids	—	—	—	3	—	—	—	12	—	1	—	—	—	—	—	—
Amphipods	—	—	2	2	—	—	—	—	—	—	—	—	—	1	—	1
Shrimps	—	5	—	2	3	—	—	1	—	2	1	24	6	—	—	3
Mud crabs	—	1	2	—	2	—	—	1	—	—	—	—	—	—	—	—
Blue crabs	—	—	—	1	—	—	—	—	—	—	—	2	11	—	—	3
Other crustacea	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lamellibranchs	—	—	2	—	—	—	—	2	—	—	—	—	—	—	—	—
Mineral	—	—	1	2	—	—	—	1	—	—	—	—	—	—	—	—
Polychaetes	—	1	—	—	—	—	—	—	—	—	—	10	—	—	—	1
Algae	1	—	—	—	—	1	—	1	—	—	—	1	—	1	—	—
Bait	89	—	—	8	—	—	—	—	—	—	—	—	—	—	—	—
Fish scales	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Unidentified	5	1	1	2	—	—	—	—	—	—	—	—	—	—	—	—
Total	246	159	121	84	50	9	6	54	4	59	110	135	66	5	2	47

TABLE III.—*Continued*

	SUMMER				*FALL*					*WINTER*				*SPRING*		
Food Items	*Head of Chesapeake Bay*	*Rock Hall, Md.*	*Galesville, Md.*	*Solomons, Md.*	*Rock Hall, Md.*	*Tilghman, Md.*	*Galesville, Md.*	*Solomons, Md.*	*Potomac River near Colonial Beach, Va.*	*Rock Hall, Md.*	*Tilghman, Md.*	*Hooper, Md.*	*James River, Va.*	*Tilghman, Md.*	*Potomac River, Va.*	*James River, Va.*
								Per Cent								
Fishes	32.9	95.1	86.8	61.7	86.0	88.9	83.3	46.2	100	89.8	97.3	72.6	66.7	60.0	100	78.8
Copepods	—	—	—	—	—	—	—	1.9	—	—	—	—	—	—	—	—
Cladocerans	24.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Isopods	—	—	6.6	14.4	4.0	—	16.7	18.4	—	5.1	1.8	—	7.5	—	—	4.2
Mysids	—	—	—	3.6	—	—	—	22.2	—	1.7	—	—	—	—	—	—
Amphipods	—	—	1.7	2.4	—	—	—	—	—	—	—	—	—	20.0	—	2.1
Shrimps	—	3.1	—	2.4	6.0	—	—	1.9	—	3.4	0.9	17.8	9.1	—	—	6.4
Mud crabs	—	0.6	1.7	—	4.0	—	—	1.9	—	—	—	—	—	—	—	—
Blue crabs	—	—	—	1.2	—	—	—	—	—	—	—	1.5	16.7	—	—	6.4
Other crustacea	1.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lamellibranchs	—	—	1.7	—	—	—	—	3.7	—	—	—	—	—	—	—	—
Mineral	—	—	0.8	2.4	—	—	—	1.9	—	—	—	—	—	—	—	—
Polychaetes	—	0.6	—	—	—	—	—	—	—	—	—	7.4	—	—	—	2.1
Algae	0.4	—	—	—	—	11.1	—	1.9	—	—	—	0.7	—	20.0	—	—
Bait	36.3	—	—	9.5	—	—	—	—	—	—	—	—	—	—	—	—
Fish scales	2.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Unidentified	2.0	0.6	0.8	2.4	—	—	—	—	—	—	—	—	—	—	—	—
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Although crustaceans comprised the only food in some instances, in only a few stomachs did their occurrence and weight suggest that they were of significant importance as food for striped bass of the sizes reported herein.

Shrimp were relatively abundant in samples taken January 18, 1937 in the vicinity of Hooper Island. One fish 195 mm long had eaten 16 shrimp weighing 11 g; another, 320 mm in length, contained 10 shrimp weighing five g in addition to two small croakers, 65 and 75 mm long, weighing six g.

Cladocerans of the genus *Leptodora* were rather abundant in the stomachs of fish taken at Conowingo. A bass 195 mm in length taken there during the summer of 1936 had about three g of *Leptodora* in its stomach in addition to a blacknose dace which weighed one g.

Crabs were found occasionally in stomachs of bass taken in more saline waters. Eight blue crabs measuring 22–24 mm from tip of spine to tip of spine and weighing a total of 53 g were found in the stomach of a 620 mm male taken on June 28, 1936 off Solomons, Maryland. Single mud crabs were found in the stomachs of two bass caught at Galesville, Maryland in August 1936. Small crabs were found more often along with other food groups.

Much of the invertebrate material examined was badly digested or broken, but some of the better specimens were saved and forwarded to the U. S. National Museum for identification. J. O. Maloney identified the isopods: the parasitic *Aegathoa oculata* (Say) and *Olencira praegustator* (Latrobe) were most numerous in the specimens submitted, but one nonparasitic form, *Erichsonella attenuata* (Harger), was identified from the stomach of a bass taken at Solomons. Waldo L. Schmitt identified the prawns and shrimp: *Crago septemspinosus* (Say) occurred in samples from Solomons, Rock Hall, Tilghman, and James River; *Palaemonetes vulgaris* (Say) and *Palaemonetes carolinus* Stimpson were identified in James River samples; and *Neomysis americana* Smith was found in samples from Rock Hall, Solomons, and Tilghman. From specimens found in the stomachs collected at Conowingo July 2–20, 1936, Chancey Juday identified *Leptodora kindtii* (Focke). C. B. Wilson examined the copepods and found one of the genus *Cyclops* in material from Conowingo taken July 2–20, 1936; he also found a parasitic copepod, *Argulus stizostethii* Kellicott, in a sample taken at Rock Hall July 21, 1936. The stomach from which the latter was taken contained two fish, one of which was an anchovy and the other an unidentified clupeoid. Mary J. Rathbun identified six samples of mud crabs from fish taken at Rock Hall and Solomons as *Rhithropanopeus harrisii* (Gould).

Isopods were found frequently in these analyses. There is the possibility, however, that not all of these were ingested as a result of direct feeding, since some of them are known to be parasitic and may have been ingested along with their fish hosts. Thus *Aegathoa oculata* and *Olencira praegustator*, both parasitic, were identified from stomach contents. Although most of these were found in the same stomach with forage fish, there were some exceptions. In the stomach of a bass 325 mm long taken on October 14, 1936 at Solomons, Maryland, 29 parasitic isopods were found together with a grass shrimp, but there was no trace of a fish host. At the same locality on October 16, one fish contained 19 isopods, 10 of which were relatively whole and were identified as *Aegathoa oculata.*

Small quantities of other crustaceans such as amphipods, mysids, and copepods were found occasionally in stomachs, but they were never present in large quantities.

Other Invertebrates and Miscellanea. Other invertebrate groups such as polychaete worms and mollusks were found less frequently in bass stomachs. Pieces of the bloodworm (*Nereis*), used as bait, were common during the summer season, particularly at Conowingo. Some annelids from the stomachs were examined by A. L. Treadwell, but they were in such poor condition that specific identification was impossible; samples taken from Tilghman, Solomons, and Rock Hall in the summer were placed in the family *Spionidae,* while a sample taken from the vicinity of Hooper Island during winter was placed in the genus *Glycera;* and one sample taken at Solomons during the summer belonged to the family *Aphroditidae.* Paul Bartsch identified the small bivalve mollusk, *Mulinia lateralis* Say, in samples taken at Galesville during August and at Solomons during October.

Some of the items found in the stomachs were unusual and could hardly be classified as food. Stones were found in the stomach contents of at least five specimens. One bass 785 mm in length and weighing 11½ pounds, taken near Solomons on August 1, 1936, had ingested two stones weighing 13.2 g, in addition to an eel and some unidentified material. Glass and an unidentified fish were found in the stomach of a bass 250 mm in length taken at Galesville August 24, 1936. Scales of shad, herring and striped bass of a size too large to be from fishes taken for food were found occasionally in the stomach samples taken at Conowingo, and it seems likely that these were thrown in the water by sportsmen while cleaning fish. Such undigestible items were probably taken accidentally while the striped bass were striking at food organisms.

REGIONAL VARIATION IN FOOD COMPOSITION

These data have been grouped in Tables III, IV, and V by seasons defined as follows: Summer, June through August; Fall, September through November; Winter, December through February; and Spring, March and April. Because of limited funds it was impossible to purchase samples at regular intervals from all localities, but the samples seem sufficient to show some seasonal variations in food composition. The areas from which samples were obtained were either salt or brackish, with the exception of the Head of the Bay, where the water is fresh.

Head of Chesapeake Bay. The data from this locality were collected from 263 bass, of which 175 had full stomachs. Most of them were caught by anglers during the summer months just below the Conowingo Dam on the Susquehanna River, where the water is fresh, and the food organisms were typical fresh water forms. Seasonal variations in food composition were observed during the several months of sampling. No *Leptodora* were found in stomachs of fish caught in June, but during July and August-September they were very frequent in occurrence, amounting to 40.2% in July and 25.6% in August-September samples.

There was a less pronounced seasonal difference among the food fishes. Eels were more common (55.6%) in June than in other months, while crappie appeared more frequently (38%) during August-September.

Rock Hall, Maryland. The fish examined from Rock Hall were caught by pounds nets, gill nets, and hook and line over three seasons (Tables III, IV, and V) and ranged in length from 180 to 485 mm. Food was found in 249 stomachs. Anchovy constituted about 50% of the food fish occurrences during the summer and fall seasons but was not found at all during the winter sampling. Menhaden was of little importance as a food item in July (3.8%), but it was found frequently in fall samples (35.3%) and then less frequently in December (27.2%). The herrings were found also as food items in all three seasons of sampling at Rock Hall, but they were found most frequently during the summer, their occurrence at this season amounting to 23%. Croaker, trout, spot, and white perch were found only during winter months. The small croaker and trout were fed upon to the extent of 17.1 and 22.9% respectively, and together they were important food items in the winter. In this locality there was a pronounced variation in food composition from season to season. Invertebrate food items ranged from about 3–14% in the three seasons of sampling, and of this food group the shrimp was found in each season of sampling.

Tilghman Island, Maryland. Fish taken from this area were captured by gill nets, pound nets, and haul seines over three seasons. Altogether, 118 bass between 280 and 425 mm with full stomachs were examined. During late fall the anchovy was a dominant food item, occurring in 55.6% of the feeding fish, but it was entirely absent during winter and early spring (Tables IV and V). Menhaden and herrings, present only in the winter samples, constituted only a very small percentage of the stomach contents. During the fall, the croaker and spot were present in small amounts, but during the winter they increased tremendously, together comprising 89.0% of food fish occurrences. Only three full stomachs were obtained during the spring, and the principal food during that period appeared to be white perch.

Solomons Island, Maryland. The fish from this locality were collected over two seasons and were obtained almost exclusively by means of hook and line. A total of 104 stomachs contained food. Anchovy was the main diet during the summer and fall months, varying from 82.4 to 51.9%. Only one full stomach was obtained during the spring and it contained herrings and menhaden. Spot was found during the summer and fall in small quantities, and croaker was present only in the fall. Other species of fish were represented in small numbers. The seasonal difference between summer and fall was slight.

James River, Virginia. Two samples of fish, one in winter with 53 full stomachs and one in spring with 37 full stomachs, were obtained from fyke nets in the lower James River just above Newport News. The two samples showed similarities in types of food; menhaden, herrings, and anchovy were the most important items, but young croakers were found during the spring.

SEASONAL VARIATIONS IN FOOD COMPOSITION

Data presented thus far show the extent of variation of bass food composition for certain localities from season to season. Differences in feeding were also observed in different regions during the same season.

Summer. Food of bass taken during this season in the fresh water immediately below Conowingo Dam consisted exclusively of freshwater species. Spottail shiner, dace, bullhead, crappie, and yellow perch were the typical species found most often in stomach contents and these species were not present in bass taken from any other region. By contrast, the anchovy was the most typical food species in stomachs of striped bass taken from salt waters during this season. The

TABLE IV. FORAGE FISH AND THE NUMBER OF STRIPED BASS STOMACHS IN WHICH THEY OCCURRED BY SEASON AND REGION

	SUMMER				FALL					WINTER				SPRING		
	Head of Chesapeake Bay	*Rock Hall, Md.*	*Galesville, Md.*	*Solomons, Md.*	*Rock Hall, Md.*	*Tilghman, Md.*	*Galesville, Md.*	*Solomons, Md.*	*Potomac River near Colonial Beach, Va.*	*Rock Hall, Md.*	*Tilghman, Md.*	*Hooper, Md.*	*James River, Va.*	*Tilghman, Md.*	*Potomac River, Va.*	*James River, Va.*
Anchovy	—	83	23	47	24	5	—	14	—	—	—	—	5	—	—	17
Bullhead	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Butterfish	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—
Crappie	17	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Croaker	—	—	—	—	—	1	—	3	—	12	52	45	—	—	—	11
Dace, blacknose	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Eel	19	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—
Flounder	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—
Goby	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—
Herring (sp?)	—	28	—	—	4	—	—	—	1	1	2	—	—	—	—	10
Branch	—	10	—	—	—	—	—	—	—	1	—	—	11	—	—	4
Glut	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	2
Menhaden	—	6	12	6	17	—	5	2	3	19	6	3	8	—	1	20
Mud Shad	—	—	—	—	—	—	—	—	1	—	—	—	2	—	—	1
Red Drum	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—
Shad	—	1	—	—	—	—	—	—	—	—	—	—	1	—	—	2
Silversides																
Common	—	—	3	—	1	—	—	—	—	—	—	—	3	—	—	2
Rough	—	1	—	—	—	—	—	1	—	—	—	—	—	—	—	—
Spot	—	—	2	2	—	1	—	1	—	4	77	47	1	—	—	—
Spottail Shiner	16	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ten pounder	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—
Trout, Gray	—	—	—	—	—	—	—	—	—	5	—	—	—	—	—	—
Trout (sp?)	—	—	—	—	—	—	—	1	—	11	—	—	—	—	—	—
White perch	—	—	—	—	—	—	—	—	—	7	2	—	4	2	1	6
Yellow perch	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Unidentified	32	33	66	1	2	2	—	4	—	10	6	15	11	1	—	2
Total	95	162	107	57	48	9	5	27	5	70	145	111	50	3	2	77

TABLE V. FORAGE FISH AND THE PER CENT OF STRIPED BASS STOMACHS IN WHICH THEY OCCURRED BY SEASON AND REGION

	SUMMER				FALL					WINTER				SPRING		
	Head of Chesapeake Bay	*Rock Hall, Md.*	*Galesville, Md.*	*Solomons, Md.*	*Rock Hall, Md.*	*Tilghman, Md.*	*Galesville, Md.*	*Solomons, Md.*	*Potomac River near Colonial Beach, Va.*	*Rock Hall, Md.*	*Tilghman, Md.*	*Hooper, Md.*	*James River, Va.*	*Tilghman, Md.*	*Potomac River, Va.*	*James River, Va.*
Anchovy	—	51.3	21.5	82.4	50.0	55.6	—	51.9	—	—	—	—	10.0	—	—	22.2
Bullhead	4.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Butterfish	—	—	0.9	—	—	—	—	—	—	—	—	—	—	—	—	—
Crappie	17.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Croaker	—	—	—	—	—	11.1	—	11.1	—	17.1	35.9	40.6	—	—	—	14.1
Dace, Blacknose	2.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Eel	20.0	—	—	1.8	—	—	—	—	—	—	—	—	—	—	—	—
Flounder	—	—	—	—	—	—	—	—	—	—	—	0.9	—	—	—	—
Goby	—	—	—	—	—	—	—	3.7	—	—	—	—	—	—	—	—
Herring (sp.?)	—	17.2	—	—	8.4	—	—	—	20.0	1.4	1.4	—	—	—	—	13.0
Branch	—	6.2	—	—	—	—	—	—	—	1.4	—	—	22.0	—	—	5.2
Glut	—	—	—	—	—	—	—	—	—	—	—	—	2.0	—	—	2.6
Menhaden	—	3.8	11.2	10.5	35.3	—	100	7.4	60.0	27.2	4.1	2.7	16.0	—	50.0	26.0
Mud Shad	—	—	—	—	—	—	—	—	20.0	—	—	—	4.0	—	—	1.3
Red Drum	—	—	—	—	—	—	—	—	—	—	—	—	4.0	—	—	—
Shad	—	0.6	—	—	—	—	—	—	—	—	—	—	2.0	—	—	2.6
Silversides																
Common	—	—	2.8	—	2.1	—	—	—	—	—	—	—	6.0	—	—	2.6
Rough	—	0.6	—	—	—	—	—	3.7	—	—	—	—	—	—	—	—
Spot	—	—	1.9	3.5	—	11.1	—	3.7	—	5.7	53.1	42.3	2.0	—	—	—
Spottail Shiner	16.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ten Pounder	—	—	—	—	—	—	—	—	—	—	—	—	2.0	—	—	—
Trout, Gray	—	—	—	—	—	—	—	—	—	7.1	—	—	—	—	—	—
Trout (sp.?)	—	—	—	—	—	—	—	3.7	—	15.8	—	—	—	—	—	—
White Perch	—	—	—	—	—	—	—	—	—	10.0	1.4	—	8.0	66.7	50.0	7.8
Yellow Perch	5.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Unidentified	33.7	20.2	61.7	1.8	4.2	22.2	—	14.8	—	14.3	4.1	13.5	22.0	33.3	—	2.6
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

low frequency of anchovy (21.5%) from the Galesville area is probably explained by the fact that approximately 60% of the fishes in the stomachs could not be identified because of decay due to inadequate preservation; hence it is probable that anchovies were actually fed upon in larger quantities than shown. Menhaden was found at Galesville and at Solomons in greater abundance than at Rock Hall, while herrings were present only in the latter locality. Blue crabs had been eaten in the vicinity of Solomons while mud crabs were present in stomachs taken at Rock Hall and Galesville.

Fall. No material was collected from the fresh-water area during this season, and samples from Galesville, Potomac River, and Tilghman Island were limited. However, comparisons can be made between the Rock Hall and Solomons Island areas. Again anchovy was dominant, with menhaden numerous (35.3%) at Rock Hall and rather scarce at Solomons Island (7.4%). At Solomons and Tilghman the croaker was present, but it was absent from the Rock Hall samples. The number of species of forage fish was greater at Solomons than in the other areas (Table IV). A similarity between the Rock Hall and Solomons areas was found in the presence of mud crabs, but they were absent from other regions during this period. The fish at Solomons apparently fed to a greater extent on invertebrates than those in other areas.

Winter. During this season, material was collected from Rock Hall, Tilghman and Hooper Islands, and the James River. The only area in which anchovy appeared as food was the James River, but even there it was not the dominant form (Table V). Although menhaden was a principal food at Rock Hall (27.2%) and was prominent also in the James River (16%), in both of these areas a great variety of forage fish was utilized and their combined frequency of occurrence exceeded that of menhaden. During December, croaker and spot were particularly abundant in stomachs of bass taken in deep water off Tilghman and Hooper Islands. The young of these commercially important fish were also present in Rock Hall samples but in the James River only small numbers of spot were found. White perch was found at Rock Hall and the James River in about equal quantities. The James River material showed the greatest variety of fish species and a larger quantity of blue crabs. Crabs were present, but in lesser amount, in samples from Hooper Island.

Spring. The collection of stomachs during the spring was limited except for the lower James River, where anchovy was found with about the same frequency as menhaden and herrings. The trend of feeding upon a great variety of fish and invertebrate species observed in winter continued on into spring, but it was only in the spring samples that the small croaker appeared as an item of food.

VARIATION IN NUMBER OF FULL AND EMPTY STOMACHS

Although the percentages of empty and full stomachs examined throughout the year were nearly equal (44.2 to 55.8% respectively) there was considerable variation among the samples. When the data were grouped according to the method of capture (Table VI), fish taken with gill nets, fyke nets, and hook and line showed the highest numbers of full stomachs, varying from about 65 to 80%, while the numbers of feeding fish taken with haul seines and pound nets were lower, about 41%. On a seasonal basis, about 50% of the stomachs were full during the summer-fall period, about 70% during winter and spring.

TABLE VI. Variations with Gear in the Number of Feeding Striped Bass, as Shown by Full and Empty Stomachs in Samples Where Method of Capture Was Known in Chesapeake Bay, 1936–37

Gear	*Number*			*Percentage*	
	Full	*Empty*	*Total*	*Full*	*Empty*
Gill Net	218	55	273	79.9	20.1
Fyke Net	87	29	116	75.0	25.0
Hook and Line	274	151	425	64.5	35.5
Haul Seine	10	14	24	41.7	58.3
Pound Net	298	437	735	40.5	59.5
Total	887	686	1573	56.4	43.6

DISCUSSION

The data show regional and seasonal variation in the food composition of striped bass in Chesapeake Bay as well as a variation in the intensity of feeding by region and season. Although the samples were obtained from eight localities, there are two main contrasting areas: the waters at the Head of the Bay, which are entirely fresh, and the remaining seven localities, which are salt and brackish.

The Conowingo Dam, impassable to the ascent of fish, impounds the Susquehanna River and thus forms a large lake, and all types of food found in samples from below this dam are typical fresh-water organisms. Most striking was the occurrence of large quantities of *Leptodora* in samples collected during July, August, and September. It seems reasonable to assume that these typical lake crustaceans floated down from the lake through the turbine gates of the dam. Many of the food fishes found in the Conowingo samples were of small size, due apparently to the generally smaller size of the striped bass themselves. Most of the samples from this region were donated by sportsmen, and a large number of them consisted of bass smaller than the lower legal size limit of 11 inches. Observations on the stomach contents from this fresh-water area disclosed the absence of young herrings and shad, although these forms were taken there by seine in August 1936. The greater portion of the stomach contents of the samples taken at the Head of the Bay (Table III) consisted of bait, the small bass undoubtedly nibbling bait from many hooks before being captured. Also, since a large number of anglers fish at the Conowingo Dam during the summer months, it is probable that discarded bait, consisting of nonindigenous bloodworms, shrimp, and fish, contributes to the diet of young bass. Merriman (1937: 33) has pointed out that bloodworms and sandworms constitute part of the food for bass in Connecticut waters.

The hydrographic conditions of the seven other regions generally are similar. Salinities range from about 9–20 $^{\circ}/_{\circ\circ}$, the James River, located near the entrance to Chesapeake Bay, probably having the highest salinity of any area sampled. Most of the forage fish found in the James River samples were also found elsewhere in the Bay, but not all of them were observed at the same place during any one season. The food in brackish water was distinctly different from that at the Head of the Bay.

It is of interest to note that exotic food species were not found in any of the areas sampled. No brackish water species were taken in the samples from the Head of the Bay, despite the fact that they are known to occur in abundance within 20 miles of the Conowingo Dam, nor were any typical fresh-water species found in samples from brackish waters. These two observations point either to an extremely rapid rate of digestion or to a slow rate of migration between fresh and brackish waters.

During summer and fall, the most common types of food in the salt-water areas of Chesapeake Bay were anchovy and menhaden, ranging from 33 to 100% in occurrence. Field observations indicated that the anchovy was abundant in Chesapeake Bay during 1936. In practically every Maryland tidal river, from the Chester to the Potomac, thousands of sea gulls were observed flying near the surface in places where bass were pursuing anchovy for food. Haddaway (1930: 8) described this phenomenon for the season of 1930, and it probably occurs every year; in particular areas the feeding activity of sea gulls serves as an indicator to fishermen in locating schools of bass.

The many schools of young menhaden seen repeatedly during the summer around the Chesapeake Bay shores suggest that this fish was abundant enough to be consumed by bass in the same quantities as anchovy. However, stomach samples indicate that this did not occur, a possible manifestation of selective feeding.

One of the fishing methods employed by Maryland anglers during the summer months is that of "chumming" with grass shrimp. This type of fishing is based on the belief that larger rock prefer shrimps to the other food which is available at that time of the year. In the material for this study, only a few stomachs of fish larger than 500 mm were available, but they did not show any marked differences from those of the smaller bass which fed almost exclusively on fish.

From the end of November to about the end of April, no anchovy was found in the upper Chesapeake Bay samples, and in samples from Maryland waters during the winter months menhaden was found only occasionally in samples from Tilghman and Hooper Islands. However, these two species were frequent in stomachs of bass taken in the James River during winter and spring (December 3, 1936 to March 29, 1937). During the cooler periods of the year the spot and croaker were the most common food items for striped bass. Winter samples from the deep water off Tilghman and Hooper Islands showed that spot and croaker comprised almost 90% of the food fish occurrences. Although spring samples were limited, white perch appeared to constitute a typical early spring food in the waters of Tilghman Island and the Potomac River. During early winter in the Rock Hall area, croaker and trout were eaten in abundance along with menhaden. Other species of fish occurred rarely. Blue crabs were present in winter and spring samples from the James River and in summer samples from Solomons Island. This feeding upon crabs parallels the distribution of crabs as established by tagging studies carried on by the Chesapeake Biological Laboratory (Truitt, 1937).

There is a possibility that the seasonal movements of fish consumed by striped bass influence the migration of this species in Chesapeake Bay. Tagging experiments by Vladykov and Wallace (1937) showed that bass move from the upper to the lower Bay in the fall and from the lower to the upper Bay during the spring. The southerly migration may be due to the pursuit of migrating food forms which are leaving the upper Bay in the fall, and the return northward in the spring may be due to the pursuit of young croakers, trout, and spot that ascend the Bay at that time.

In California waters, according to Scofield (1928:37) and Shapovalov (1936), the striped bass commonly feeds on its own young in great quantities, but in the material from Chesapeake Bay, no small striped bass were found in the stomachs of the larger fish. Also, it has been reported that California bass feed on the jellyfish, *Velella*, but no comparable food was found in the stomachs of Chesapeake fish, although medusae and ctenophores are at times extremely common in these waters.

It is of interest to compare Merriman's (1937) observations on about 150 full stomachs from the Connecticut area with those derived from the present study. The most common food items during the winter months in Chesapeake Bay, spot and croaker, are not mentioned for Connecticut. Although the croaker is seldom found that far north, the spot ranges from Massachusetts southward. It is especially interesting to note that Merriman did not find anchovy in his material, since this form, according to Bigelow and Welsh (1925: 125), is abundant around Woods Hole and southward; and as pointed out previously, it is the most typical summer food in Chesapeake Bay. Merriman listed the silverside (*Menidia menidia notata*), as one of the most common food items of striped bass in the Connecticut area. Although silversides are abundant in Chesapeake Bay, according to Hildebrand and Schroeder (1928: 187–192), only nine specimens were found in 1,736 stomachs. It appears that bass from Chesapeake Bay, although they may feed on silversides, show a preference for anchovies. Probably for the same reason, killifishes (*Fundulus*) were not found in the local striped bass even though they are extremely abundant in the area studied; two species of *Fundulus* were mentioned by Merriman as common types of food. From these facts it would seem that bass exhibit food preferences and, at least to some degree, actively seek specific foods. During the summer months menhaden was next to anchovy in importance as bass food. Menhaden was also reported by Merriman (1937) as one of the most common food items in Connecticut.

Table VII shows the number of full and empty stomachs by season. The greater part of the material, collected from June to October, was obtained by hook and line, and the stomachs from fish taken by this method of capture probably do not reflect the same ratio between full and empty stomachs that might be expected in a more random sample, since only feeding fish would be expected to bite. No doubt stomachs secured from fish taken with nets would be more representative and indicative of the normal feeding intensity. According to Table VI, fish taken by haul seines and pound nets show about the same ratio between full and empty stomachs, whereas those taken with gill and fyke nets during winter give the highest percentage of full stomachs. From these data it appears that the number of full stomachs increased to about 80% by early spring. To some extent, this observed increase in the percentage of full stomachs may reflect a slower rate of digestion during cold weather, but local fishermen have observed that during December and January the rock do feed extensively and may be taken by deep trolling. This abundant feeding during the colder period of the year, the prespawning season, may be due to the physiological demands of sexual maturation. The spawning period for bass at the Head of Chesapeake Bay is probably protracted, with the major spawning starting in May and continuing on into June. During the period from June 1–6, 1936, Vlakykov collected 29 bass (205–710 mm) in pound nets at Turkey Point, Maryland, all of which were sexually ripe and some showed running spawn; of the 29 stomachs, only two contained a trace of food—a fact which suggests that mature bass do not feed heavily in the Chesapeake Bay during spawning. That bass cannot be caught in appreciable numbers with hook and line by anglers during late spring is a further indication of the partial cessation of feeding during the period of spawning. Toward the last of June angling improves, which may indicate another period of active feeding.

TABLE VII. VARIATIONS WITH SEASON IN THE NUMBER OF FEEDING STRIPED BASS AS SHOWN BY FULL AND EMPTY STOMACHS

Season	*Number*			*Percentage*	
	Full	*Empty*	*Total*	*Full*	*Empty*
Summer	503	520	1023	49.2	50.8
Fall	99	90	189	52.4	47.6
Winter	324	146	470	68.9	31.1
Spring	43	11	54	79.6	20.4
Total	969	767	1736	55.8	44.2

Although these data probably represent the trend of feeding of striped bass, observations made since the completion of the study point out some of the limitations of sampling. Two factors make it difficult to obtain representative samples: first, this species can regurgitate its food, and second, food may be more concentrated in the capturing gear than in nature. Presumably regurgitation is linked with the stress of capture, which would tend to increase the percentage of empty stomachs in a sample. On the other hand, there is a strong possibility that bass taken in pound nets, fykes, and to a more limited extent in haul seines, may gorge while in the nets just before they are landed. Although the mesh-size of pound nets is usually large enough to permit the escape of many forage fish, including anchovies and smaller menhaden, it is a matter of common observation that these species tend to concentrate in the pound pockets and remain there until the net is nearly out of the water. Presumably the forage fish behave similarly in other impounding gear. Furthermore, while impounded, bass sometimes "break," a typical concomitant of feeding. Thus it is entirely possible that the method of capture does influence the pattern of feeding as observed from stomach-content analyses. Within Chesapeake Bay proper, it would be difficult to explore this problem unless it were approached experimentally, since more than one form of gear is seldom fished at the same time and place. However, in some of the rivers, small pound-nets, stake gill-nets, and haul seines are fished in close proximity, and a comparative study of striped bass stomachs taken simultaneously in the same area by the different types of gear might be of interest.

SUMMARY

1. The present study is based on an examination of 1,736 stomachs removed from striped bass taken in Chesapeake Bay from June 1936 to April 1937. Of the stomachs studied, 55% contained food which weighed 8,945 g, or about 20 pounds.

2. The following food-groups were found in the bass stomachs: fishes, crustaceans, mollusks, polychaete worms, and fragments of algae. Undigestible materials such as sand, pebbles, pieces of glass, and fish scales were occasionally present.

3. Fish constituted the dominant food-group, amounting to 95.5% by weight of the total food content of the stomachs examined. This food-group occurred in 32 to 100% of the stomachs, depending on season and area.

4. Within the fish group, anchovy and menhaden ranked first, varying in occurrence from 55 to 100%. Spot and croaker were the next most important food fishes, varying from about 30 to 90%.

5. Next to the fish in importance were crustaceans, which ranged in occurrence from about 4 to 46% by frequency but less than 2% of the total by weight. Remaining invertebrate groups were a negligible part of the food.

6. There was a distinct seasonal variation in food composition. During the summer and fall seasons of 1936, the principal food in salt-water regions were anchovy and menhaden, while during the winter months spot and croaker were dominant. Early in the spring the most typical food was the white perch. Two species of herring were common during the spring and early summer.

7. There was a regional variation in food between fresh-water and salt-water areas. In the former, a number of fresh-water species

including crappie, yellow perch, spottail shiner, dace, and bullhead were commonly present; there was also an abundance of *Leptodora*, a crustacean. The above species were lacking in salt-water regions, where anchovy, menhaden, spot, and croaker were the principal foods. Blue and mud crabs were present in stomachs from salt-water areas, but they were absent in samples obtained from fresh water.

8. There was a tendency toward reduction of feeding during late May and early June, a period which corresponds with the spawning period for this species.

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AN "UNUSUAL" YELLOWFIN TUNA (*NEOTHUNNUS MACROPTERUS*) FROM THE WATERS OF THE NORTHERN LINE ISLANDS IN THE CENTRAL PACIFIC OCEAN.—During an exploratory fishing cruise of the U. S. Fish and Wildlife Service vessel, HUGH M. SMITH, in waters of the central Pacific Ocean in May and June, 1951, a female tuna, weighing 24 pounds, was captured which differed distinctly from the fish being landed from a surface school of yellowfin tuna (*Neothunnus macropterus* Temminck and Schlegel). The specimen was caught by hook and line on June 1 while chumming off Palmyra Island, 1½ miles WSW of Sand Island, where water depths exceed 2000 fathoms.

The coloration of the fresh specimen was striking: the upper surface of the body was steel-blue, shading into silvery-gray on the sides and white on the belly; a series of oblique transverse pale silvery lines, alternating with similarly colored rows of dots, was present on the side, the latter forming an irregular pattern on the caudal peduncle; the first and second dorsals, anal, and caudal fins were dusky and edged with black; the anterior one-third of the pectoral fins was silvery-gray, shading into dusky posteriorly and edged with black; both the dorsal and anal finlets were jet black; the body and fins were without yellow markings.

Based on these external color markings, the specimen at first appeared to be a bluefin tuna, either *Thunnus thynnus* (Linnaeus) or *Thunnus maccoyi* (Castelnau), except for the oblique transverse silvery bars on the sides of the body, the black finlets, and the pectoral fins; the latter are much longer than is common in either of these species of comparable size. Furthermore, the gill-raker count precluded its assignment to either of these species. Godsil and Holmberg (1950, Calif. Div. Fish and Game, Fish Bull. 77: 1–55) gave gill-raker counts for *T. thynnus* and *T. maccoyi* as 10 to 15 + 21 to 25, and 12 + 22 to 24, respectively. This specimen has a gill-raker count of 9 + 21 on the first gill arch of both the right and left sides, which is clearly within the range for the yellowfin tuna, *Neothunnus macropterus*. Also, the specimen differed from *Kishinoella tonggol* Bleeker, the latter having a gill-raker count of 5 to 8 + 14 to 17 (Serventy, 1942, Jour. Council Sci. and Ind. Res., 15 (2): 101–12).

Other meristic counts and measurements, after the methods of Marr and Schaefer (1949, U. S. Fish and Wildlife Service, Fish. Bull. 47: 241–44), were made aboard the vessel at the time of capture, and are presented in Table I. These measurements consistently fall within the range of variation for *Neothunnus macropterus* of comparable size, but lie outside the ranges for other tuna species for which there are published data.

An examination of the internal anatomy (made after three month's preservation in formalin) showed the following features: The apex of the caecal mass is located on the right side of the body, which appears to be rather uncommon in the tunas. The liver is composed of three lobes, the right lobe the longest. The central portions of all three lobes lack black striations on the ventral surfaces; however, these surfaces are marked inconspicuously with a very fine network of blood vessels on the central portions and along the edges. Furthermore, a swim bladder is present which occupies nearly two-thirds the length of the body cavity; in shape and size it is comparable to the descriptions of this structure in *Neothunnus macropterus* as given by Godsil and Byers (1944, Calif. Div. Fish and Game, Fish. Bull. 60: 54–57).

Based on the morphometric measurements, gill-raker counts, the plain ventral surfaces of the lobes of the liver and the presence of a well developed swim bladder, the specimen tentatively is identified as an unusual *Neothunnus macropterus*.

TABLE I

MEASUREMENTS, IN MILLIMETERS, AND MERISTIC COUNTS OF AN "UNUSUAL" SPECIMEN OF *Neothunnus macropterus* CAPTURED IN THE LINE ISLANDS IN JUNE, 1951

Total length (fork length)	863
Head length	241
Snout to origin of first dorsal fin	265
Snout to origin of second dorsal fin	459
Snout to origin of anal fin	504
Snout to insertion of ventral fin	276
Insertion of ventrals to anterior edge of vent	244
Greatest body depth	216
Pectoral fin, length	234
Pectoral insertion to origin of first dorsal	126
First dorsal, basal length	196
Second dorsal, basal length	93
Spread caudal (fin was frayed)	275
Longest dorsal spine, length	97
First dorsal spine, length	97
Second dorsal fin, length	136
Anal fin, length	140
Length longest dorsal finlet	32
Iris, diameter	36
Maxillary, length	97
Caudal peduncle, least depth	22
Caudal peduncle, greatest width at keels	80
Spines in first dorsal	14
Rays in second dorsal	14
Dorsal finlets	8
Rays in anal	14
Anal finlets	8

Verbal information obtained from Mr. Phil Palmer, Manager of the Fanning Island Plantation, Ltd., indicated that tunas similar to that described above occasionally have been caught in the waters off Fanning Island. It is possible that the specimen represents a race that has become established in the Line Islands area. The specimen is preserved at the Pacific Oceanic Fishery Investigations laboratory as POFI Cat. No. 5314.—FRED C. JUNE, *U. S. Fish and Wildlife Service, Box 531, University of Delaware, Newark, Delaware.*

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Observations on a Specimen of Bluefin Tuna *(Thunnus thynnus)* Taken in Hawaiian Waters

FRED C. JUNE[1]

The bluefin tuna, *Thunnus thynnus* (Linné), has been reported from Hawaiian waters by several authors (Fowler, 1923 and 1928; Jordan and Evermann, 1926), however, it appears only rarely in the commercial tuna catches from this area. The last confirmed report of the occurrence of this species was a landing made by a commercial long-line boat off the coast of Waianae, Oahu, in 1939. There have been reports of bluefin tuna being taken along the Kona coast of the island of Hawaii, but they have been infrequent and the identifications were not validated.

On October 3, 1950, a specimen weighing 223 pounds was captured on long-line gear by the vessel *Ilima* while fishing off the southwest coast of Oahu, at approximately 21° 26′ N., 158° 27′ W. and at an estimated depth of 60 fathoms.

Measurements on this specimen were taken on October 6, 1950, at the Kyodo Fishing Co., Ltd., Honolulu, where the fish catch of the *Ilima* was unloaded for disposition. Viscera, for subsequent laboratory examination, were also obtained at this time. The various measurements, according to the methods described by Marr and Schaefer (1949), and meristic counts are given in Table 1 for the benefit of those interested in a critical study of the morphometric characters and distribution of this fish.

In all anatomical characters examined, this specimen agreed with Godsil and Holmberg's (1950) detailed description of the Pacific bluefin tuna, *Thunnus thynnus*. It also showed remarkable agreement with Kishinouye's (1923) description of *Thunnus orientalis*, except for the author's notation regarding the division of the ureter as it enters the kidney. Kishinouye (1923: 309) states, "In *Thunnus orientalis* the two ureters meet in a figure like U, and in other forms of the Japanese tunnies they meet like the figure V." In the Hawaiian specimen, the ureters met in a figure V at a point 31 mm. within the posterior margin of the kidney. The left branch continued anteriorly for a short distance, then diverged sharply, whereas the right branch curved outward gradually from the point of division. Both observations follow Godsil and Holmberg's findings for *T. thynnus*.

Another point of apparent difference between the description given by Godsil and Holmberg and that of Kishinouye concerns the branching of the coeliac-mesenteric artery. Kishinouye (1923: 378) indicates the presence of an abortive No. 1 branch in *T. orientalis*. He states, "In [the genus *Thunnus*] the first branch is abortive and nourishes the oesophagus only, or is entirely absent." Godsil and Holmberg (1950: 42) found no No. 1 branch in *T. thynnus* and conclude, "Occasionally a capillary-size vessel is present, originating approximately where the No. 1 branch should be, and like it running to the oesophagus. This vessel is so small, and is moreover one of several originating in this region and nourishing the adjacent tissues, that it was not considered homologous with No. 1 branch." There was no evidence of a

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[1] Pacific Oceanic Fishery Investigations, Honolulu, Hawaii. Manuscript received May 11, 1951.

No. 1 branch in the Hawaiian specimen, but inasmuch as the circulatory system was not injected, this blood vessel may have been overlooked.

The coloration of the finlets in the Hawaiian specimen differed from descriptions for this form given by other authors. Both the dorsal and anal finlets were bright yellow with broad black borders, similar to those of the big-eyed tuna, *Parathunnus sibi*. Kishinouye (1923: 439) notes that in *T. orientalis* the dorsal finlets are yellow, whereas the anal finlets are silvery; both are without a black margin. Godsil (1945: 187) states that in *T. thynnus* ". . . the finlets, though frequently yellow, are not edged with black." Roedel (1948: 60) similarly remarks that *T. thynnus* "lacks . . . the black edging of the finlets found on the yellowfin tuna when caught." These discrepancies may be simply individual color variations that exist within the species or real differences that show variation with geographical distribution.

Until a more detailed comparison is made between *T. thynnus* from the eastern Pacific and *T. orientalis* from the western Pacific, the specific standing of these forms remains in doubt.

TABLE 1

MEASUREMENTS* AND MERISTIC COUNTS OF A SPECIMEN OF *Thunnus thynnus* FROM HAWAIIAN WATERS

Measurements	
Total length	1740
Head length	497
Snout to insertion first dorsal	531
Snout to insertion second dorsal	950
Snout to insertion anal	1069
Snout to insertion ventral	540
Insertion ventrals to anterior edge vent	560
Greatest depth	450
Spread caudal	561
Length longest dorsal spine	189
Length first dorsal spine	189
Length second dorsal	268
Length anal	251
Length longest dorsal finlet	59
Diameter iris	44
Length maxillary	25
Least depth caudal peduncle	47
Greatest width caudal peduncle at keels	144
Meristic Counts	
First dorsal spines	14
Second dorsal rays	15
Dorsal finlets	8
Second dorsal plus dorsal finlets	23
Anal rays	15
Anal finlets	7
Anal plus anal finlets	22
Gill rakers (first gill arch)	12+24

* Measurements are in millimeters.

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Repeated Semiannual Spawning of Northern Oysters

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In Long Island Sound, as well as in ecologically similar areas, the spawning season of oysters, *Crassostrea virginica,* is confined to the period extending approximately from the last week of June until the beginning or middle of September. Thus the season is comparatively short and occurs once a year. It is the latter circumstance that suggested studies designed to determine whether the gonad development and spawning of the oysters were of the exogenous type—initiated and regulated by periodical seasonal changes of environment—or of the endogenous type—controlled by a pattern confined within the organism itself.

The question has been answered in part by experiments which showed that ripening of gonads in oysters could be achieved even in midwinter by placing the oysters for several weeks in warm water of about 20° C (*1*). It still remained uncertain, however, that this was not merely a case of precocious development of gonads which would make the oysters unable to undergo normal gametogenesis the following summer. To settle this an experiment was devised to find whether the oysters are able, under certain conditions, to accumulate and discharge spawn in a normal way at least twice a year, at intervals of about six months, and to do so for two or three successive years.

The experiment began in the spring of 1947 when a group of approximately 250 adult, individually numbered oysters was suspended on a float in Milford Harbor, Connecticut. By the middle of June, when the oysters reached ripeness, they were brought into the laboratory and induced to spawn. After spawning they were returned to the harbor. Samples of the gonads taken approximately once a month for histological studies showed that by the middle of September the oysters had almost recovered from the summer spawning.

Toward the end of November the oysters began to hibernate. Late in December 1947 they were brought from the harbor, which at that time was covered with a layer of ice, and placed in the laboratory in running sea water at a temperature of about 4° C. Using our method for conditioning mollusks for winter spawning (*2*), the temperature was gradually increased a few degrees every two or three days until it was slightly over 20° C, after which the oyster became ripe within three to four weeks. They were induced to spawn in January and February 1948, discharging normal gametes.

Following spawning, and partial recovery of the oysters, the temperature of the water was gradually decreased. This process resembled fundamentally the condition occurring in our natural waters in late summer and fall. In March 1948 the oysters were returned to Milford Harbor, where the water temperature was only about 4° C—i.e., cold enough to make them hibernate.

Some of the oysters were returned to the harbor while their gonads were still in the process of active resorption and while they contained undischarged eggs. When examined early in May, at which time the water temperature was still below 10° C, the oysters remained in about the same condition. Apparently the temperature between the dates of return to the harbor in March and the examination was too low to permit active resorption of the remaining gonad material. However, with the increase of temperature, which reached 16° C by the end of May, the resorption proceeded more rapidly, and was soon completed.

Between the end of May and the middle of June 1948 the oysters again underwent and completed gametogenesis and were easily induced to spawn when brought into the laboratory. After the spawning they were once more returned to the harbor and went through the normal process of gonad resorption and glycogen accumulation, eventually entering hibernation late in the fall. Thus the condition and behavior of the oysters in the summer and fall of 1948 were basically the same as during the corresponding period the previous year, regardless of their unusual extra reproductive activities during the winter.

In January 1949 the oysters were again brought into the laboratory, conditioned, and induced to spawn. Then, following the procedure described for the preceding year, they were once more returned to the harbor. They again spawned in the summer of 1949. Thus within a period of two years, June 1947–June 1949, the oysters were made to develop gonads and discharge normal spawn on five occasions at approximately six-month intervals.

The experiments have shown that the processes of gonad development and spawning of these oysters are not of the endogenous type; i.e., there is nothing in their physical pattern that will not permit reproduction oftener than once a year, provided the ecological conditions are favorable for all aspects of the physiological activities involved in this complex process.

The experiments have also demonstrated that the oysters, in developing gonads, showed no dependency on seasonal changes in such factors as light, tidal rhythm, precipitation, small variations in salinity, or other changes that usually occur during the spring and early summer when the gonads of oysters are rapidly developing. It has also been shown that gonad development of oysters is not dependent on certain types of plankton organisms that are present in the water only during the spring and summer, the time of normal gametogenesis and spawning.

Although the observations reported here concern oysters only, we think, nevertheless, that the conclusions may also apply to some other lamellibranchs. For example, in our work with the clam *Venus mercenaria,* several individuals have been spawned in the January-July-January pattern. This ability of some Northern lamellibranchs to be conditioned for spawning at more frequent intervals than under natural conditions offers an interesting and practical method for studies of physiological ecology, genetics, and other aspects of their behavior.

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TEMPERATURE REQUIREMENTS FOR MATURATION OF GONADS OF NORTHERN OYSTERS

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Gonad development and spawning of oysters (*Crassostrea virginica*) of our North Atlantic coast are well-defined seasonal phenomena. For example, in Long Island Sound, where extensive oyster beds are located, spring gonad development commences during the first part of May and spawning begins during the end of June or the first week in July (Loosanoff and Engle, 1942). There is no doubt that the rate of progress of gametogenic activities and the beginning of spawning of oysters are to a large extent influenced by the temperature of the surrounding water.

In the opinion of many students the period required for maturation of the gametes of the European oyster, *O. edulis*, is a function of time and temperature (Voisin, 1933; Orton, 1937; Korringa, 1941, and others). Few studies of a similar nature have been made, however, on the American oyster, *C. virginica*. Perhaps the only works dicussing effects of temperature on gonad development were those of Nelson (1928a), who thought that spawning of *C. virginica* should be expected approximately 160 degree-hours after the temperature of the water reaches and remains at the 20.0° C. level, and of Loosanoff (1942), who described seasonal gonadal changes of oysters of Long Island Sound and referred to the temperatures of the water prevailing during the different stages of gonad development and at spawning. In general, however, many aspects of the effect of temperature on the gonad development of *C. virginica* remained unknown.

The experiments described in this article were designed to ascertain the number of days needed for oysters of both sexes kept at different but constant temperatures to develop first mature cells; to reach the physiological state at which they can be induced to spawn by thermal or chemical means; and to reach the condition at which they will be ready to spawn normally, without any artificial stimulation. We hope that our article will contribute toward the understanding of the dependence of individuals and of populations upon ecological factors, such as temperature.

We wish to express our appreciation to our colleagues, Charles A. Nomejko, for assisting us in different phases of these studies, to David W. Calhoun for the statistical treatment of the data, and to Professor Thurlow C. Nelson of Rutgers University for reviewing the manuscript.

METHOD

The oysters used in these experiments ranged in age from three to five years. They were collected in winter when the temperature of the water over the beds was near 0.0° C. In the laboratory the oysters were separated into five groups and placed in trays with running, cold sea water having a temperature of about 8.0° C., just high enough to allow the oysters to come out of hibernation. Twenty-four hours later the temperature of the water running in the trays was raised within 4 to 8 hours to 10.0, 15.0, 20.0, 25.0 or 30.0° C. and steadily maintained, within ± 1.0°C., at those levels until the end of the experiment.

In the first series of experiments small samples of oysters consisting of 5 to 15 specimens were taken at 5-day intervals for gross examination and histological studies (Loosanoff and Davis, 1949). In later experiments, however, each sample consisted of 50 oysters and when needed the oysters were examined daily. The quantitative data of this article are based on the latter samples.

The method of conditioning oysters to develop spawn in winter was, in principle, the same as that described several years ago (Loosanoff, 1945). It was modified only in the respect that instead of keeping the oysters in aquaria, the water of which was changed at certain intervals, they were kept in shallow trays through which water of the desired temperature was running continuously. The oysters were fed a rich culture of plankton which was automatically and continuously added to the running water.

Examination of the oysters was made according to the following procedure: Before the oysters were ripe enough to be induced to spawn, all 50 individuals constituting each sample were opened and the content of their gonads examined under a microscope to determine the number of males with active sperm, number of females with fertilizable eggs, and the number of immature oysters (Tables I–IV). All males containing active sperm were considered physiologically mature although not necessarily ready to spawn. Possession of fertilizable eggs was determined by adding mature sperm to the egg suspension made from each female containing large ovocytes. Formation of the polar body was taken as the criterion that the eggs were fertilizable.

After the oysters were kept long enough at the conditioning temperatures to be approaching the state in which they could be induced to spawn the procedure of the examination was changed as follows: Each of the 50 oysters constituting a sample was placed in a separate spawning dish, which was filled with water of the same temperature as that at which that group of oysters was conditioned. Then all the oysters were subjected to chemical stimulation consisting of the addition of sperm and egg suspensions to the water in the spawning dishes.

Ninety minutes after the beginning of the chemical stimulation all the oysters that failed to respond were further stimulated by an increase of the water temperature. After another period of 90 minutes the oysters that failed to spawn were opened and their gonads examined for the presence of active sperm or fertilizable eggs.

OBSERVATIONS

Control samples

Gonads examined at the beginning of the experiment contained small undeveloped follicles typical for hibernating oysters (Loosanoff, 1942). The male sex cells were in the early stages of spermatogenesis, predominantly spermatogonia or early spermatocytes. In the females the follicles contained mostly indifferent cells, some ovogonia and a few young ovocytes 15–18 μ in diameter. In both sexes most of the space between the body wall and the digestive diverticula was occupied by the vesicular connective tissue which surrounded the small islands formed by the follicles (Fig. 1). The oysters were in good condition and contained large quantities of glycogen.

10.0° C. group

Even the most advanced oysters of this group, examined 35 days after the beginning of the experiment, showed only a slight development of their gonads. In the females the largest ovocytes were only 18–20 μ in diameter and contained virtually no yolk (Fig. 2). In the males, there were secondary spermatocytes and a few spermatids, but no spermatozoa. Even in these individuals, which constituted about 5 to 6 per cent of the samples, such development took place only towards the end of the experiment. In the other oysters of this temperature group the gonads even then resembled the winter condition.

It is interesting that in the 10.0° C. group the anastomosis of the follicles and gametogenesis were so slow even though these oysters, judging by the quantities of feces produced, were feeding more actively than those kept at the temperature of 25.0 or 30.0° C. Moreover, at the end of the experiment the meats of the low-temperature oysters still contained approximately as much glycogen as they had at the beginning. Considering these conditions, which indicated that the oysters were kept in a relatively favorable environment, it seems apparent that the depressed gonad development of those oysters was principally due to the low temperature.

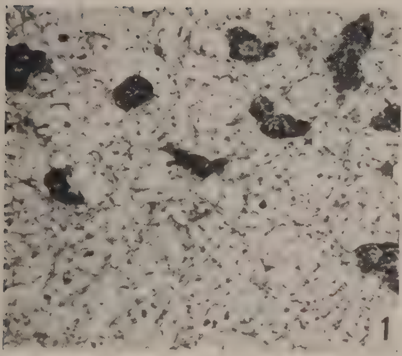
TABLE I

Number and per cent of oysters, kept for different periods at 15.0° C., that were induced to spawn, or showed presence of mature gametes. Number and per cent of immature oysters and those with sex undetermined are also given. Each sample composed of 50 oysters.

Days of conditioning	Induced to spawn				Unspawned				Per cent		
	By chemical stimulation		By chemical and thermal stimulation		Mature gametes		Immature gametes		Spawned	Unspawned but with mature gametes	Immature
	Male	Female	Male	Female	Active sperm	Fertilizable eggs	Sex recognizable but immature	Sex undetermined			
10	—	—	—	—	5	0	11	34	—	10	90
15	—	—	—	—	6	0	14	30	—	12	88
20	—	—	—	—	6	3	16	25	—	18	82
25	—	—	—	—	16	6	10	18	—	44	56
30	0	0	0	0	26	9	11	4	0	70	30
35	0	0	2	1	17	17	7	6	6	68	26
40	0	0	3	0	19	19	7	2	6	76	18
45	0	0	4	2	16	20	7	1	12	72	16
55	1	0	14	5	3	27	0	0	40	60	0

15.0° C. group

During the first five days of exposure the oysters showed little gametogenic activity and their gonads still remained in winter condition. The advanced males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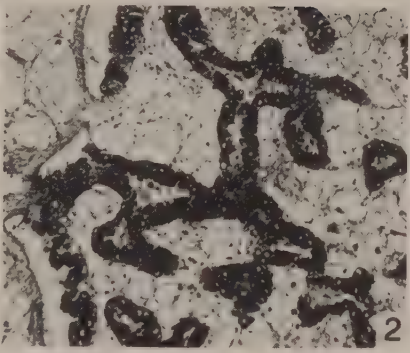
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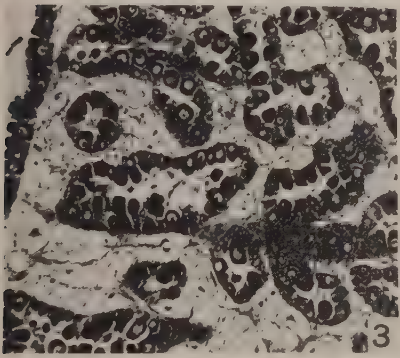
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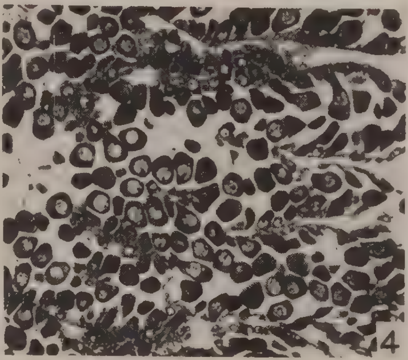
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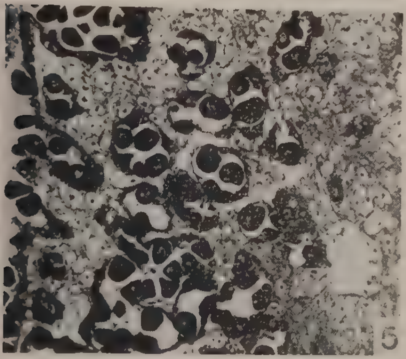
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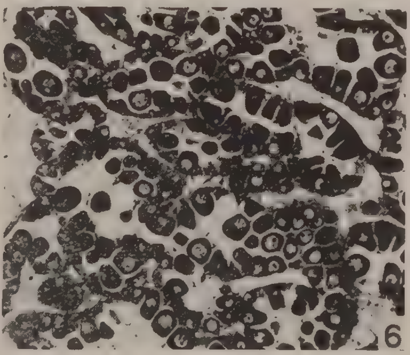
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FIGURE 1. Winter gonad of oyster showing undeveloped follicles surrounded by connective tissue. × 112.

FIGURE 2. Gonad of most advanced female oyster of the group kept 35 days at 10.0° C. × 112.

FIGURE 3. Gonad of female oyster showing proliferating follicles containing growing ovocytes; 15 days at 15.0° C. × 112.

FIGURE 4. Gonad of female oysters; 40 days at 15.0° C. × 112.

FIGURE 5. Partly discharged gonad of female oyster; 55 days at 15.0° C. × 112.

FIGURE 6. Gonad of female oyster approaching ripeness; 13 days at 20.0° C. × 112.

showed a slight proliferation of follicles but gametogenesis proceeded only as far as the formation of spermatids. After 10 days the female oysters still showed little progress, while in the males a slight anastomosis of the follicles was noticed and in five of them a few spermatozoa were found (Table I). Towards the 15th day the largest ovocytes were already about 35 μ in diameter, but the vesicular connective tissue still occupied a large part of the interfollicular spaces (Fig. 3).

By the 20th day 9 oysters, representing 18 per cent of the sample, contained active sperm or fertilizable eggs, while 16 other oysters possessed recognizable sex cells (Table I). Thus, on this date the sex of 50 per cent of the oysters composing the sample was already recognizable.

On the 25th and 30th days attempts were made to induce the oysters to spawn. They were first stimulated by the addition to the water of a suspension of ripe spermatozoa or eggs, and later by a rapid increase of the temperature to about 32.0° C. Some oysters, probably females, moved their shells in typical rhythmic spawning motions, but no eggs were discharged.

Spawning was successfully induced for the first time on the 35th day (Table I). However, of 50 oysters composing the sample only three, two males and one female, spawned and then only after the combined effects of chemical and thermal stimulations. The eggs obtained in this spawning developed into normal larvae.

By this time a difference in the gonad development of the individuals composing the samples became especially pronounced. The thickness of the gonadal layer varied from almost 0.0 to 3.0 mm. and while the most advanced oysters could be induced to spawn, the least advanced possessed gonads so undeveloped that their sex could not be easily determined (Table I).

Between the 35th and 45th days the oysters continued to develop, their enlarged gonadal follicles coming in contact with each other, while the vesicular connective tissue, which was so prominent earlier in the development, had largely disappeared (Figure 4). Yet, even on the 45th day none of the oysters could be induced to spawn by chemical stimulation alone.

After 55 days all the oysters had either fertilizable eggs or active sperm, and 20 of them, constituting 40 per cent of the sample, were induced to spawn (Table I). Of these, however, only one responded to chemical stimulation alone, while all others required the rapid increase in temperature. It is possible that this happened because several oysters in the sample had already discharged some spawn, and were, therefore, comparatively indifferent to the stimulating effect of sex products. That some of the oysters may have spawned was shown by histological examination of the gonad tissue taken from the oysters of an auxiliary experimental group, some of which showed partially discharged gonads, characterized by contracting follicles and the invasion of connective cells into the interfollicular spaces (Fig. 5).

At the end of the 90-day period an egg and sperm suspension was added to the trays to determine if the oysters would respond to this stimulation and begin spawning, even if there were no increase in temperature. Within a few minutes after the addition of the suspension almost all the oysters in the tray commenced spawning and continued to do so for about two hours. During the spawning the temperature steadily remained at 15.8° C. The eggs collected from this spawning developed into normal larvae.

20.0° C. group

The stimulating effect of this temperature was clearly seen early in the experiment. At the end of the first five days 28 per cent of the oysters already contained either active sperm or fertilizable eggs (Table II). After eight days the oysters were first induced to spawn by a combination of chemical and thermal stimuli, and two days later some oysters responded to chemical stimulation alone (Table II). Although some ripe eggs were found in the females after only five to ten days of exposure, nevertheless, such eggs still represented a minority of the follicular cells.

Table II

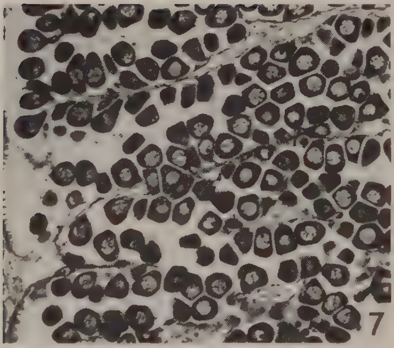
Number and per cent of oysters, kept for different periods at 20.0° C., that were induced to spawn, or showed presence of mature gametes. Number and per cent of immature oysters and those with sex undetermined are also given. Each sample composed of 50 oysters.

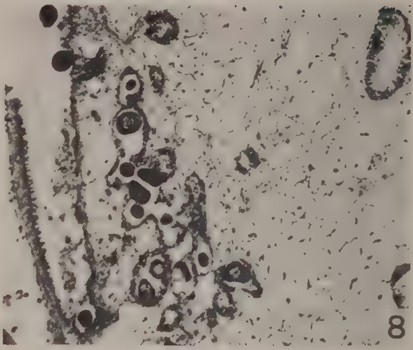
Days of conditioning	Induced to spawn				Unspawned				Per cent		
	By chemical stimulation		By chemical and thermal stimulation		Mature gametes		Immature gametes		Spawned	Unspawned but with mature gametes	Immature
	Male	Female	Male	Female	Active sperm	Fertilizable eggs	Sex recognizable but immature	Sex undetermined			
5	0	0	0	0	9	5	7	29	0	28	72
8	0	0	2	0	14	4	18	12	4	36	60
10	2	0	11	0	9	7	14	7	26	32	42
13	1	0	7	8	8	16	9	1	32	48	20
15	3	3	9	6	4	14	10	1	42	36	22
18	6	6	3	11	8	12	2	2	52	40	8
20	1	1	16	12	1	18	1	0	60	38	2
25	0	0	19	6	4	21	0	0	50	50	0

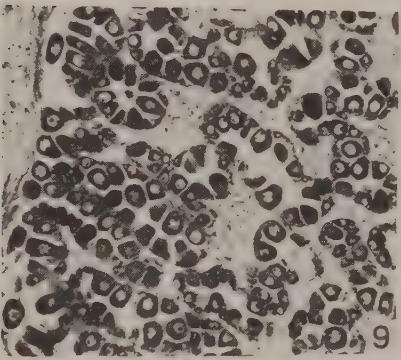
Again, as in the preceding temperature classes, the individual differences among the oysters of the same group were striking. While 26 per cent of the oysters kept at 20.0° C. for ten days could be induced to spawn, 7 others still possessed gonads resembling the winter condition (Table II). This condition of slow gonad development persisted even though the oysters were feeding vigorously and showed rapid growth of shell. Similar individual differences in gonad development were also found in oysters growing under natural conditions in Long Island Sound (Loosanoff, 1942).

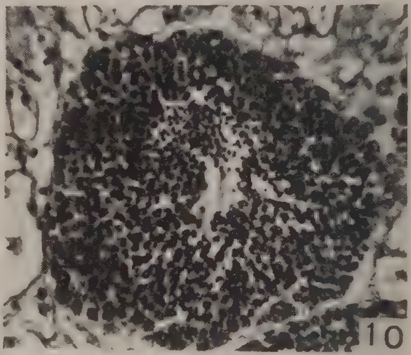
The spawning behavior of the females within the samples also showed that they were in physiologically-different states of ripeness. Some of them did not respond at all to stimulation. These were usually immature individuals, the sex of which could not be determined. Others moved their shells as in spawning but released no eggs. Still others discharged a few apparently immature eggs measuring only 45 μ, *i.e.*, about 5 μ smaller than normal eggs. Finally, there were females that discharged normal eggs which developed into healthy larvae. The ratio between these groups changed continuously, as can be judged from the data in Table II.

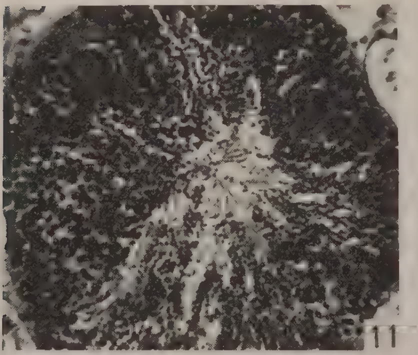
Between the 13th and 18th days many oysters were either approaching ripeness (Fig. 6) or were ripe (Fig. 7). At the latter date 52 per cent of the oysters











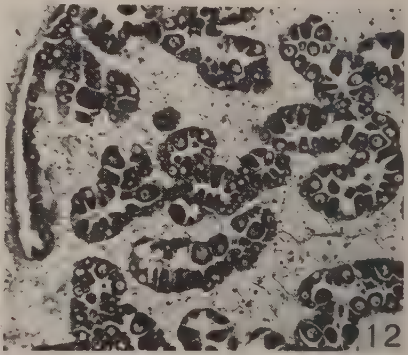


Figure 7. Gonad of ripe female oyster; 18 days at 20.0° C. × 112.

Figure 8. Gonad of female oyster in advanced stage of spawning; 25 days at 20.0° C × 112.

Figure 9. Gonad of female oyster containing some ripe eggs but still not quite mature; 8 to 10 days at 25.0° C. × 112.

Figure 10. Gonadal follicle of male oyster showing few ripe spermatozoa in center of lumen; 3 days at 30.0° C. × 475.

Figure 11. Gonadal follicle of male oyster; 5 days at 30.0° C. × 475.

Figure 12. Gonad of female oyster containing some fertilizable eggs; 5 days at 30.0° C. × 112.

spawned, when stimulated, and the number of individuals with sex undetermined was only one or two per sample of 50. After 20 days 98 per cent either spawned or contained ripe gametes.

On the 20th day of exposure the number of oysters that could be induced to spawn showed a considerable decrease, as compared with the record of the 18th day (Table II). Between these two dates some of the oysters had apparently spawned in the natural, unprovoked way, and the presence of their sex products in the surrounding water may have made them unresponsive to this type of stimulation when it was applied experimentally a day or so later. This contention is supported by the observation that on the 25th day of the experiment none of the oysters could be induced to spawn by chemical stimulation alone. Histological studies of their gonads also showed that some were already in the typical post-spawning condition characterized by contracted follicles still retaining some ripe eggs, a large number of phagocytes, and a rapid invasion of connective tissue throughout the space between the body wall and the digestive diverticula (Fig. 8). Such oysters, obviously, could not be easily stimulated and, therefore, were not included in the number of oysters induced to spawn on that date. Instead, they were classified together with those that were unspawned but contained active sperm or fertilizable eggs. This explains why on the 25th day of exposure the number of oysters that could be induced to spawn showed a decrease, while the number of individuals which were unspawned but contained ripe gametes showed an increase (Table II).

25.0° C. group

In this group rapid gametogenesis and proliferation of gonadal follicles began within the first few days. After five days 17 oysters, constituting 34 per cent of the sample, already contained mature gametes (Table III). Of these 13 were males containing active sperm and the rest were females with fertilizable eggs. In both sexes, however, there were only a few ripe cells, indicating that the oysters were just entering the state of ripeness.

TABLE III

Number and per cent of oysters, kept for different periods at 25.0° C., that were induced to spawn, or showed presence of mature gametes. Number and per cent of immature oysters and those with sex undetermined are also given. Each sample composed of 50 oysters.

Days of conditioning	Induced to spawn				Unspawned				Per cent		
	By chemical stimulation		By chemical and thermal stimulation		Mature gametes		Immature gametes		Spawned	Unspawned but with mature gametes	Immature
	Male	Female	Male	Female	Active sperm	Fertilizable eggs	Sex recognizable but immature	Sex undetermined			
5	—	—	—	—	13	4	10	23	—	34	66
6	0	0	0	0	19	8	11	12	—	54	46
7	0	0	8	4	7	13	10	8	24	40	36
8	5	1	3	1	13	17	10	0	20	60	20
9	1	3	7	5	8	13	9	4	32	42	26
10	9	13	3	5	5	10	3	2	60	30	10

By the end of the seventh day some of the oysters were induced to spawn by the combined effects of chemical and thermal stimuli, and the next day five males and one female responded to chemical stimulation alone.

After 9 and 10 days of conditioning the samples gave 32 and 60 per cent of spawners respectively, and at the latter date the number of immature oysters was only 10 per cent (Table III). However, some of those that were capable of spawning still possessed gonads containing many immature cells. This condition is well illustrated in Figure 9, where together with mature ovocytes there are many unripe cells. Furthermore, the large quantity of connective tissue in the interfollicular spaces indicated that further growth of the follicles was still to occur.

Mass spawning of the oysters of this temperature group took place during the eleventh day. In some earlier experiments, however, mass spawning of one group kept at 25.0° C. occurred on the ninth day (Loosanoff and Davis, 1949). In both cases the spawning was unprovoked since the temperature remained steadily at 25.0° C. and no sex products capable of stimulating the experimental oysters could be present in the water flowing into the trays, because the experiments were conducted in February when the oysters in the Harbor, from which our water supply is obtained, were hibernating and, obviously, could not release any spawn.

30.0° C. group

This group, as a whole, responded extremely rapidly to the effect of high temperature and after three days of exposure 18 per cent of the oysters already possessed physiologically-ripe cells (Table IV). Although the most advanced females showed expanding follicles already containing a few fertilizable eggs, their gonads, nevertheless, still had a large quantity of connective tissue separating the follicles. In the males rapid spermatogenesis was in progress, already resulting in a few ripe spermatozoa in the centers of the lumens of the follicles (Fig. 10).

TABLE IV

Number and per cent of oysters, kept for different periods at 30.0° C., that were induced to spawn, or showed presence of mature gametes. Number and per cent of immature oysters and those with sex undetermined are also given. Each sample composed of 50 oysters.

Days of conditioning	Induced to spawn				Unspawned				Per cent		
	By chemical stimulation		By chemical and thermal stimulation		Mature gametes		Immature gametes		Spawned	Unspawned but with mature gametes	Immature
	Male	Female	Male	Female	Active sperm	Fertilizable eggs	Sex recognizable but immature	Sex undetermined			
3	—	—	Not Employed		7	2	3	38	—	18	82
4	—	—			26	3	6	15	—	58	42
5	16	3			7	3	8	13	38	20	42
6	15	12			10	1	8	4	54	22	24
7	22	13			1	2	6	6	70	6	24

After five days the oysters were successfully induced to spawn. Because they were conditioned at the temperature of 30.0° C. it was impractical to use a much higher temperature to induce spawning and, therefore, chemical stimulation alone was used. Nineteen oysters of the total number of 50 spawned but the quantities of spawn released were still small. Histological examination of the gonads showed that although the males conditioned at 30.0° C. for five days (Fig. 11) had considerably more mature sperm than after three days (Fig. 10), the unripe cells, nevertheless, still predominated. The same could be said for the females in which ripe ovocytes were not too common (Fig. 12).

After six days 54 per cent of the oysters were induced to spawn. Yet, 24 per cent were still immature and in four per cent the sex could not be determined (Table IV). After seven days 70 per cent could be spawned, and in one of the experiments an unprovoked mass spawning took place at the end of the seventh day. Both sexes participated in the spawning, the males discharging large quantities of sperm, but the number of eggs released still remained comparatively small.

By the tenth day the gonads of the oysters were already in advanced post-spawning stages, characterized by contracted follicles similar to those shown in Figures 5 and 8.

DISCUSSION

As has already been mentioned, in studying the maturation of gonads of oysters kept at different but constant temperatures we were primarily interested in the number of days needed for formation of the first physiologically-mature gametes in each sex. We were also interested in finding how soon oysters can be induced to spawn by artificial means, *i.e.*, by the addition of sex products or by a rapid increase in temperature and, finally, how soon they would begin to spawn normally, without the help of any artificial stimulation.

Our experiments showed that the temperature of 10.0° C. is not high enough to induce gametogenic activities in most of the oysters, and in those few in which such activities were initiated, the development proceeded at an extremely slow rate. Apparently this temperature was too low to permit the conversion of glycogen and other materials stored in the oyster bodies into sex products. While the exact mechanism of this complex process is still not understood, it is thought that it involves the action of a certain enzyme or chain of enzymes, which is retarded, or completely inhibited, at low temperatures.

There are ample indications that some processes in animals, including oysters, are slowed down by low temperature more than others, thus showing that the effect of such low temperature is, obviously, differential. For example, while the growth of the shell of the oysters of our waters may proceed even at a temperature of one or two degrees below 10.0° C., the gonad development at such a temperature is either entirely arrested or proceeds at such a slow rate that a successful completion of that process cannot be expected. Perhaps this is a good example of the so-called developmental or biological zero of Bělehrádek (1935) who considers such a zero as the highest temperature threshold at which a certain protoplasmic activity is still arrested by cold.

Our observations, that at a temperature of 10.0° C. even the most advanced oysters did not form spermatozoa after 35 days of exposure, differ from those of Nelson (1928b) who, in his studies of oysters in Barnegat Bay, found that "active spermatozoa may be found in a few oysters at temperatures as low as 9°–10° C., Table I." Nelson's table shows, however, that the temperature data which he offers were the averages for the week preceding the date of collection of the gonad samples. It is possible, therefore, that the maximum temperature during, or prior to, this period exceeded 10.0° C., causing spermatogenic activities which resulted in the formation of a few spermatozoa. Nevertheless, the results of our controlled experiments are in full agreement with the field observations of Nelson (1928a) who emphasized the wide individual differences often found in the condition of the gonads of oysters collected at the same time and from the same bed.

The experiments also demonstrated that under certain conditions ripening of gonads and spawning of oysters of both sexes may be accomplished at a temperature of only about 15.0° C. These experiments prove rather conclusively that the old conception that 20.0° C. is the minimum temperature at which spawning of *C. virginica* is possible does not hold for the oysters of Long Island Sound.

Laboratory observations on ripening of gonads at such a relatively low temperature corroborate the studies in Long Island Sound, which showed that spawning of oysters may take place at a temperature as low as 16.4° C. (Loosanoff, 1939). Recently we have found that in nature oysters may possess ripe gonads in early summer when the temperature of the surrounding water is only 14.6 to 15.4° C. On July 1, 1948 samples of oysters were taken from two of our collecting stations located in Long Island Sound at a depth of 30 feet. At the time of collection the temperature of the water at the first station was 14.3° and at the second, 15.4° C. The highest temperature recorded that summer at the first station, prior to collection of the sample, was 14.6° C., while at the second station it was 15.4° C. These oysters were placed in the laboratory in separate trays of slowly running water at about 22.0° C. A few hours later the oysters began to spawn copiously, both sexes participating in the act. The fertilized eggs were cultured and became normal larvae.

A similar experiment was repeated in early June, 1949. The oysters were collected from a depth of 35 feet, where the highest temperature recorded for the season was only 14.5° C. Again the oysters spawned a few hours after they were placed in warm water. Thus, the oysters were near the spawning condition at the time of collection even though the highest temperature the water had reached that season was only about 15.0° C.

Since spawning is possible at temperatures lower than 20.0° C., Nelson's (1921) conclusion that if the temperature of the water fails to reach 70.0° F., (21.2° C.) and remain at that level for some time, the oysters will not spawn at all, should be regarded as not applicable to the oysters of Long Island Sound. For the same reason Nelson's (1928a) suggestion that spawning of *C. virginica* may be expected to begin approximately 160 degree-hours after the temperature of the water has reached 20.0° C. is not true for Long Island Sound oysters. We think that the discrepancies between our observations and Nelson's may be explained on the basis that the two studies were made in geographical areas where ecological conditions are different, and where the local populations of oysters may possess significantly different physiological traits. That such physiologically-different groups of oysters may exist was recently shown by Stauber (1950) who by reviewing published and some unpublished records concluded that there appear to be three physiological races of oysters, *C. virginica,* which require different minimum temperatures at which they are capable of spawning. Stauber showed that the race with the lowest critical temperature is not found in Canada, at the northern limit of the geographical range of the species, but in Long Island Sound, some 600 miles airline farther south. Loosanoff and Nomejko (1951), by conducting experiments in Milford Harbor, Connecticut, with oysters brought from different geographical areas along the Atlantic coast, found that the breeding temperature requirements of the northern oysters were somewhat lower than those of the southern groups, thus corroborating Stauber's conclusions and suggesting once more that some physiological requirements of oysters of different geographical districts may be decidedly different. We would also like to mention that our colleague, Professor Thurlow C. Nelson, called our attention to the most interesting fact that many years ago Lamarck from shell characteristics alone designated the Long Island Sound oyster as *Ostrea borealis*, which he believed to be a species distinctly different from *O. virginica* (now *Crassostrea virginica*).

TABLE V

Per cent of oysters of both sexes with mature gametes and estimated number of females in samples of 50 oysters kept at temperature of 15.0, 20.0, 25.0 or 30.0° C. for different numbers of days. Calculated days' exposure compensated for inequalities in sex ratio are also shown.

Days exposed	Temperatures in °C.											
	15.0			20.0			25.0			30.0		
	Compensated days exposed	% Oysters with mature gametes	Estimated number of females	Compensated days exposed	% Oysters with mature gametes	Estimated number of females	Compensated days exposed	% Oysters with mature gametes	Estimated number of females	Compensated days exposed	% Oysters with mature gametes	Estimated number of females
3										3.0	18	27
4										5.2	58	18
5				4.9	28	28	4.9	34	28	5.7	58	23
6							6.1	52	27	6.7	76	24
7							6.1	64	33	7.6	76	25
8				7.8	40	29	7.8	80	29			
9							7.9	74	33			
10	9.8	10	29	10.6	58	26	8.8	90	33			
13				11.2	80	34						
15	14.5	12	30	12.9	78	34						
18				16.1	92	33						
20	17.4	18	34	18.4	98	32						
25	25.9	44	28	26.6	100	27						
30	35.9	70	23									
35	35.6	74	29									
40	43.2	82	27									
45	44.9	84	30									
55	52.3	100	32									

As is well known, the rate of metabolic processes of an animal increases almost to the extreme upper limit of the temperature at which this animal carries on its activities. This is especially well noticed in poikilothermous animals, the body temperature of which is usually at or near that of their environment. To express more or less accurately the influence of temperature on biological phenomena and to demonstrate the relation existing between temperature and the speed of physiological processes, a number of formulae have been proposed by many students including the most often quoted Krogh (1914), Arrhenius (1915) and Bēlehrádek (1935). It is not the purpose of our article to evaluate the relative merits of the different formulae, except to mention that although there is not a universally acceped mathematical expression for the effect of temperature upon the rate of biological processes, it is widely recognized, nevertheless, that some of the formulae, including those mentioned above, offer biologists a tool for an approximate solution of the problems and, at times, for prediction of the results of the studies concerning relationships between temperature and physiological processes, such as gonad development or spawning.

Choice of indices of the gonadal development of a group of oysters is somewhat arbitrary. The two most satisfactory for examination were the number of individuals with active sperm and the number with fertilizable eggs. Accordingly, an analysis was made of the sums of these two indices, as a percentage in each sample of 50 oysters (Table V). This percentage is hereafter called the degree of maturity of the sample. It was then transformed to the probit scale, and compared with the exposure time on a logarithmic scale. The four groups of samples at the different temperatures gave four series of points. By the method of maximum likelihood four parallel straight lines with the slope 4.343 were fitted, one to each series. Deviations did not appear to come from systematic curvature or non-parallelness of the fitted lines.

This analysis indicated that (1) since straight lines follow use of the log-time scale, individual differences may be explained by variability in the rates of development of different individuals. (2) Parallelism of the four lines is evidence that a given temperature increase affects all individuals in the same way, accelerating their rates of development by the same factor. (3) The slope of the fitted lines measures the variation of the oyster population with respect to differences in time required to reach maturity. For example, at a given temperature, it will take the slowest developing 20 per cent of the population over 2.5 times as long to reach maturity as it does the fastest 20 per cent (Fig. 13).

Our experiments have shown that males mature earlier than females (Tables I–V). Therefore, we would expect that samples largely female would be slow and those predominantly male would be farther advanced than the average. Since the sex of oysters with poorly developed gonads could not be recognized, the actual number of each sex in some samples was unknown. Hence, the sexes could not be analyzed separately, and random fluctuations in sex ratio have presumably disturbed the temperature averages, making comparison uncertain. A refinement of the analysis was obtained by allowing for the estimated proportion of females in each sample. An appropriate allowance was then subtracted from the actual time for predominantly female samples and added to the time of the samples with more than the average number of males.

Estimated sex ratios in each sample were based on the preliminary fitted lines, by dividing the number of sexually indeterminate individuals roughly in proportion to the expected unripe fractions for each sex. The resulting estimate, expressed as number of females, is shown in Table V. Based on these estimates an allowance was calculated, using partial regression, leading to compensated exposure times: $x = 1.03035x_1 - .01212x_2 + .31226$, where x_1 is the original log-time, x_2 is the estimated number of females in the sample and x is the log of the compensated time. The latter is the time that would presumably be required for a sample of 50 oysters containing 28.37 females, which is the weighted average for the experiment, to reach the same degree of maturity as the given sample. This is presented in Figure 13, showing degree of maturity plotted against compensated exposure time, with a straight line of slope 4.343 fitted for each of the four temperatures. This fit is satisfactory after compensation for sex ratio: chi-square equals 30.8, with 22 degrees of freedom, which is just at the 10 per cent level of significance.

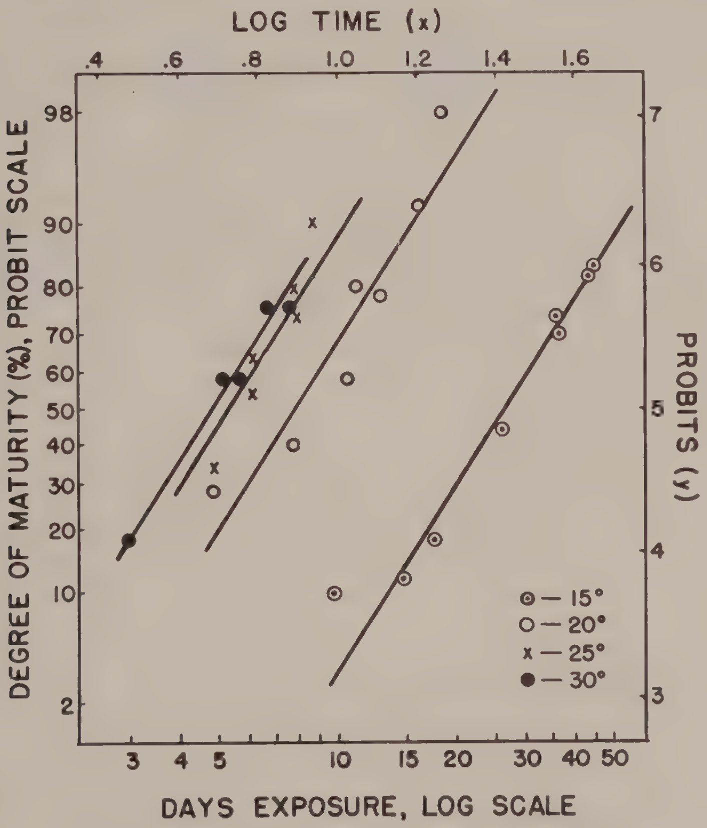


FIGURE 13. Degree of maturity (%) in samples of 50 oysters plotted against period of exposure to four experimental temperatures. Each period of exposure is compensated for the estimated sex ratio of the sample.

From the equation for each line, $y - \bar{y} = 4.343\ (x - \bar{x})$, where y is the probit of degree of maturity and $\bar{x}$ and $\bar{y}$ are the average values of x and y for a given temperature, the average time required for 50 per cent of oysters to develop mature gametes can be calculated for each temperature. This corresponds to the value of x when $y = 5$. For the four temperatures this average time was:

15.0° C. – 26.5 days
20.0° C. – 7.9 days
25.0° C. – 5.4 days
30.0° C. – 4.9 days

Their error is estimated as about 10 per cent. The lowest observation at 15.0° C. has been omitted in computing the value 26.5, because of its apparent discrepancy from other values at that temperature (Fig. 13).

We may fit these four points by a simple curve, from which average times needed for development of mature gametes can be estimated for intermediate temperatures (Fig. 14). The equation for the curve used is:

$$D = 4.8 + 4205e^{-.3554T}$$

where D is the average time needed, T is the temperature in degrees centigrade, and e is the base of the natural logarithms. The fit of this curve to the four established points is within their estimated error. This, however, is an empirical curve, and its theoretical significance, or its possible value for temperatures outside the range of the experiment, may be questioned.

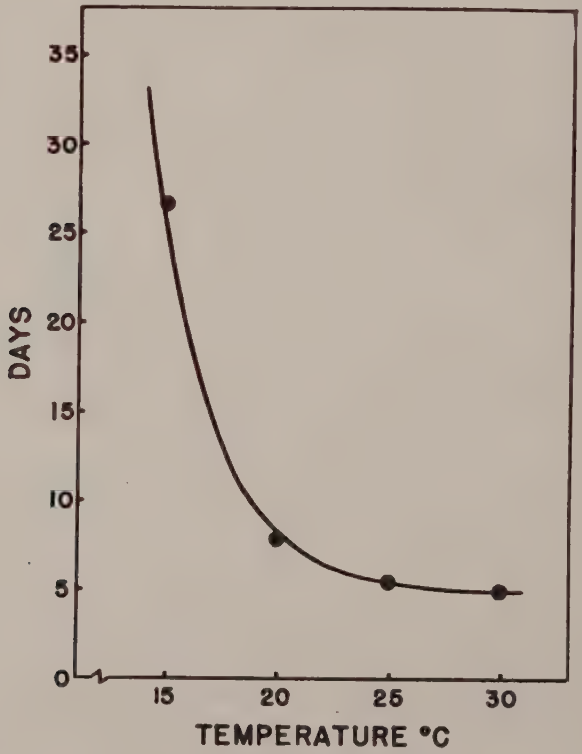


FIGURE 14. Average time needed for 50 per cent of an oyster population to develop mature gametes at different temperatures.

We have noticed that the quantity of glycogen contained by the oysters at the beginning of gonad development may control the quantity of spawn that will be produced. If the oysters are "poor," *i.e.*, containing little glycogen, they usually do not develop good gonads. For example, our attempts to condition for spawning in winter several groups of oysters shipped to us from the Florida waters of the Gulf of Mexico failed because those oysters were thin and watery, containing virtually no glycogen. Similar experiments with poor oysters from other bodies of water gave the same results.

In concluding this discussion it may be mentioned that the knowledge of the thermal history of the organisms prior to their exposure to the experimental conditions is important in interpreting the results of the experiment and in forming conclusions. Fry (1947), in his paper on the effects of the environment on animal activities, cites numerous examples where the thermal past of fishes reflects profoundly on their behavior under experimental conditions. It is possible, therefore, that if the groups of oysters used had been acclimated to a higher temperature than almost 0.0° C., which was our starting point, somewhat different results would have emerged from an experiment similar to ours. Furthermore, since it has been suggested that there are different physiological races among the population of *C. virginica* of our Atlantic coast, which require different temperatures for spawning (Stauber, 1950; Loosanoff and Nomejko, 1951), it is possible that our northern oysters, which are acclimated to comparatively low temperature, would, under the same experimental conditions, show a more rapid rate of gonad development and could be induced to spawn earlier than the oysters of other geographic regions, such as the Gulf of Mexico which, ecologically, maintains an entirely different temperature regime from Long Island Sound. Such relations to temperature conditions were found for several aquatic animals, including certain species of amphibians (Moore, 1939) where northern populations survived lower temperatures and bred earlier than the more southern groups.

SUMMARY

1. The temperature of 10.0° C. was not high enough to induce normal gametogenic activity in most of the oysters. Even the most advanced individuals of this group showed only slight development of the gonad after exposure to this temperature for 35 days. Apparently this temperature is near the biological zero for this activity.

2. Ripening of gonads and spawning of oysters of both sexes were achieved at a temperature as low as 15.8° C.

3. Wide individual differences in the extent of gonad development among the individuals constituting the same groups were commonly found.

4. In all temperature groups, ranging from 15.0 to 30.0° C., the physiologically ripe gametes were generally formed earlier in the males than in the females.

5. At 15.0° C. the most advanced males contained a few ripe spermatozoa on the 10th day. Fertilizable eggs were found on the 20th day and spawning was induced by the 35th day. At 20.0° C. oysters with ripe spermatozoa and fertilizable eggs were found on the fifth day. Spawning was induced on the 10th and 13th days in males and females respectively. At 25.0° C. ripe spermatozoa and fertilizable eggs were found by the fifth day. Spawning was induced on the seventh day. At 30.0° C. ripe spermatozoa and a few fertilizable eggs were found three

days after the hibernating oysters were taken from their winter environment and placed at this temperature. Spawning was induced on the fifth day.

6. The average time at each of the experimental temperatures required for 50 per cent of the oysters to develop mature gametes was calculated to be:

15.0° C. – 26.5 days	25.0° C. – 5.4 days
20.0° C. – 7.9 days	30.0° C. – 4.9 days

To estimate the average time needed for development of mature gametes at temperatures intermediate to those given above, a simple curve is offered based on the equation:

$$D = 4.8 + 4205e^{-.3554T}$$

where D is the average time needed, T is the temperature, and e is the base of the natural logarithms.

7. The quantity of glycogen in the oysters at the beginning of gonad development may control the quantity of spawn produced.

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ECOLOGICAL EFFECTS OF WINTER CONDITIONS ON TROUT AND TROUT FOODS IN CONVICT CREEK, CALIFORNIA, 1951

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ABSTRACT

In 1951, winter studies were conducted at the Convict Creek Experiment Station of the U. S. Fish and Wildlife Service located at 7,200 feet elevation in the Sierra Nevada Mountains near Bishop, California. These were designed to extend knowledge of winter conditions in stream environments and to bring to light problems requiring further investigation at this season. Common stream survey methods were employed to procure and analyze data.

Snowfall was meager at Convict Creek in 1951, but freezing temperatures induced extensive ice formations. Surface ice immobilized screens and other objects protruding from the water, yet provided the trout with abundant shelter. Frazil and anchor ice had a more pronounced effect on stream life and water temperatures than surface ice. When subsurface ice was present, the water was at or very close to the freezing point, regardless of weather conditions or time of day. Anchor ice formed and dispersed in a daily cycle that caused wide fluctuations in stream flow. Minimum water flow at night often left secondary channels empty, while morning peak flows scoured the stream with ice fragments, washing loose debris and bottom fauna. Trout were active in the freezing water and fed regularly throughout the winter. Trout were caught on bait when the water was 32° F.

Large numbers of aquatic organisms were dislodged by fluctuating flows and became available as food for trout. Clear indications were obtained of high seasonal fluctuations in the abundance of bottom organisms. Adult stoneflies and dipterans emerged on warm days during the winter.

A comparison between the numbers of stream bottom organisms present, drift foods, and foods consumed by trout, gave a positive correlation. In cold weather, trout consumed large numbers of mayfly and stonefly nymphs, while dipterans predominated in trout stomachs over the entire winter. Rainbow and brown trout of similar lengths and stomach volumes differed in the number of organisms eaten by each in that rainbow trout ingested larger quantities of small organisms than did brown trout.

Wild trout suffered an initial mortality in early January that was caused by heavy subsurface ice which blocked stream flow into side-channels. Very few dead trout were found after this occurrence. The over-winter survival of marked trout approximated 50 percent in 1950-51.

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INTRODUCTION

Studies of winter conditions in trout waters have been neglected in many areas. As was pointed out by Hubbs and Trautman (1935), inland fishery research has usually been limited to summer months because working conditions are better and there seldom are both living and laboratory facilities available and easily accessible for winter investigations. The Fish and Wildlife Service of the U. S. Department of the Interior has such facilities at its Convict Creek Experiment Station in Eastern California. In cooperation with the University of California it conducted a study of winter conditions over the period from November, 1950, through April, 1951. The main effort was directed toward discovering the effect on trout of low water temperatures, ice formation and dispersal, snow, and other ecological factors.

The principal species of fish in the area of Convict Creek where these studies were made are brown trout, *Salmo trutta* Linnaeus, and rainbow trout, *Salmo gairdneri* Richardson. Brown trout are by far the more abundant. Only rarely is an eastern brook trout, *Salvelinus fontinalis* (Mitchill), taken. Suckers and cyprinids are common in lower Convict Creek and in Lake Crowley, into which it flows some 3 miles below the Convict Creek Station.

THE STUDY AREA

The Convict Creek Station is located on the eastern escarpment of the Sierra Nevada Mountains in Mono County, California, at an elevation of 7,200 feet. Convict Creek rises in snow-fed lakes near the crest of the Sierras, plunges precipitously down a canyon, dropping 2,300 feet into Convict Lake. From here, the stream drops about 400 feet in 2 miles to the experimental area. Convict Creek below the lake flows rapidly through a boulder-strewn, tree-bordered canyon for about 1 mile, after which it enters flat meadow-like areas bordered on both sides by wide sagebrush flats. There the water course averages about 10 feet in width and has a bed of rubble, gravel, and sand. Natural spawning areas of fine gravel are found at frequent intervals. The pines, cottonwoods, birch, and alders that border the stream in the canyon are replaced by willows in the meadow. There is little aquatic vegetation except for small patches of *Ranunculus*. Under-cut banks, holes, submerged logs and debris provide excellent natural cover.

The experimental stream system now in use consists of four, one-quarter-mile channels. The full flow of the stream is divided in half, each half then flowing through two sections which are screened at their upper and lower ends. A flood control structure is provided above the area to divert excess flood waters around the four experimental stream sections. The winter studies described in this report were made principally within the areas encompassed by the Convict Creek Station, though some of the observations were made in adjacent waters both above and below the station area proper.

Winters at Convict Creek are characterized by heavy snowfalls, high winds, and low temperatures. Snow usually averages 2 to 4 feet deep on the level and wind-borne snow, blown from adjacent high ridges, often bridges the entire width of the creek.

The winter of 1950-51 was comparatively mild in that less than 2 feet of snow fell during the period of study, and low temperatures alternated with periods of mild weather. Nights were generally cold and clear while days were bright and windy. Only two periods of extreme cold weather occurred in 1951. These were severe enough to cause heavy ice formations in the stream and permitted observations of their effects on stream ecology.

METHODS AND EQUIPMENT

The techniques and equipment employed were those generally used in stream survey work. Stream bottom organisms were collected with the Surber square-foot sampler. This device, with a coarse screen fender, was used as a stationary net to capture stream drift organisms. It was staked to the bottom of the stream for 15-minute intervals at various times of day and under varying stream conditions.

Trout for stomach analyses were taken by seine, trap, and angling. Water flow records (Table 1) secured from the City of Los Angeles were supplemented by additional flow measurements taken with a White current meter. Continuous air and water temperatures were taken by means of a Taylor recording thermometer ranging from 0°F. to 100 F. and graduated in 1° intervals. Temperatures taken from these charts (Table 2) were read to the nearest 0.5°F. Supplementary water-temperature measurements were made with a Foxborough resistance thermometer, the vernier of which was graduated in half degrees and interpolated to the nearest 0.1°F. Water temperatures reported here were taken with the resistance thermometer, unless otherwise noted.

TABLE 1.—*Mean monthly discharge of Convict Creek from November, 1950, through April, 1951.*

Month	Stream flow cubic feet per second		
	Mean	Maximum[1]	Minimum[1]
November	18.9	44.3	6.5
December	23.0	35.1	13.7
January	10.6	13.7	1.3
February	10.4	13.9	9.2
March	8.3	10.8	7.2
April	11.2	15.4	7.7

[1] Refers to extreme daily means occurring within the month

TABLE 2.—*Mean monthly maximum and minimum air and water temperatures in Fahrenheit and mean times of occurrence at Convict Creek, California, January 1 through March 31, 1951.*[1]

Month	Air temperatures				Water temperatures					
	Monthly mean		Monthly mean		Monthly mean		Monthly mean		Minimum water temperatures[2]	
	Maximum	Time	Minimum	Time	Maximum	Time	Minimum	Time	Average length of period	Total hours
January	44.5	2:00 P.M.	16.3	4:15 A.M.	37.9	3:00 P.M.	32.8	5:45 A.M.	9:45 P.M.—1:30 P.M.	222
February	47.5	2:30 P.M.	18.1	4:00 A.M.	40.2	3:15 P.M.	32.9	5:30 A.M.	12:15 A.M.—11:15 A.M.	166
March	53.2	2:45 P.M.	19.9	3:30 A.M.	44.5	3:30 P.M.	32.8	5:30 A.M.	1:00 A.M.—10:00 A.M.	117

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[1] Compiled from thermograph charts, Taylor recording thermometer

[2] Temperatures of 32° F. or lower.

ICE FORMATION IN STREAM

Three types of ice may appear in streams in boreal climates. Surface or sheet ice which forms over the surface of the water is most common. Frazil and anchor ice, two less known types, form within the water (subsurface). Frazil is an extremely soft, grey ice composed of fine spicules and may appear as feathery wisps undulating in the current, as clumps at the surface of the water, or as a stationary, slushy mass occupying the entire depth of the water. Anchor ice appears as a grey, translucent coat over immovable objects in the stream bed. It is composed of crystals larger than those of frazil, which makes it more granular and gives it some rigidity. Both subsurface ices, if free from particulate foreign matter, appear brilliantly white when removed to the atmosphere.

Surface ice formations grow from the edge toward the center of the stream until a complete layer is formed. It then thickens by crystallization on the underside as heat is transferred upward through the ice. In Convict Creek, sheet ice formed over the surface of slow pools and shelf-like along stream banks in riffle areas, reaching a thickness of 8 inches in some localities. Light accumulations of snow rendered it opaque.

Although surface ice may form when subsurface waters are well above freezing, subsurface ice never appears until the whole water mass reaches the freezing point. The time at which the stream reaches its lowest temperature coincides with the first appearance of subsurface ice. Barnes (1906) recorded the minimum temperature of the St. Lawrence River at —0.0068°C. (31.988°F.). In an experiment with a container of water that was agitated as it was cooled, Barnes also found the lowest water temperature was —0.014°C. (31.975°F.) at the time ice first appeared. Convict Creek waters showed a minimum temperature slightly below 32°F. Within minutes, particles of ice became abundant and the temperature increased slightly but retained a position between the minimum and 32°F. In Table 2, it will be noted that water temperatures of 32.0°F. or lower existed for a total of 222 hours in January, 166 hours in February, and 117 hours in March.

Both forms of subsurface ice may result from tiny, clear, colloidal particles which resemble ice but lack its true crystalline form. Colloidal discs formed quickly and extensively in Convict Creek on clear, cold nights when excessive terrestrial heat radiation lowered the stream temperature to freezing. They were secured from the stream by means of a cheesecloth strainer and measured up to 3 millimeters in diameter.

Frazil ice forms throughout the water as minute, irregular crystals, the extent of the formation being largely dependent upon the agitation of the water. Turbulence may be produced both by swift currents in steep riffles and by wave action from strong winds. Frazil ice was also formed from the crystalline growth of colloidal particles and from supercooled snow falling into water which was at or below the freezing point.

The volume of frazil formed on a cold windy day may be immense, for Barnes (1928) reports accumulations up to 80 feet in thickness beneath surface ice on the St. Lawrence River. Large quantities of frazil appeared in Convict Creek on only one day during this study.

Terrestrial radiation is commonly accepted as the cause of anchor ice formation. At Convict Creek anchor ice formed only at night and apparently never under an overcast sky or opaque layer of surface ice, since these tended to reflect the heat being radiated from the earth below. The cloud-like masses of anchor ice that formed nightly made up the bulk of the ice. Anchor ice was observed to form soon after the appearance of colloidal discs: first, on the rubble at the downstream ends of pools; second, on the rough substrate in riffles; and lastly, at the bottom of pools. The amount of this ice formed in any one night was determined by depth, turbulence, and rate of heat radiation from the water. Most of the colloidal particles, as well as any frazil crystals present, adhered to the coarse anchor ice, grew, and became part of that formation.

EFFECTS OF STREAM ICE

The effects of ice formation on stream life are both beneficial and harmful (Hazzard, 1941). Needham (1938) notes that snow-bridges completely covering small streams afford insulation against both cold and predators. Later, Smith (1947), in similar work on Convict Creek, found that wind-drifted snow combined with stream ice blocked an experimental stream channel and caused a 4-hour cessation of flow and a consequent draining of water from the channel into the substrate.

Sheet and shelf ice offer excellent shelter to trout along otherwise open stretches of stream. Brown and rainbow trout in Convict Creek took advantage of the increased cover. They could usually be frightened from these retreats by breaking loose a section of shelf ice. Surface ice greatly impeded observations and recovery of trout. It also caused much disturbance to the stream banks and bottom when water surges broke it loose. At such times, large masses of ice with embedded twigs, leaves, and other vegetation were swept over shallow riffles in heaps of tumbling cakes.

Subsurface ice, being far more abundant than surface ice, had a much greater effect. Frazil caused extensive damage to Convict Creek on January 19. In the early morning hours, winds of extreme velocity (estimated at 80 miles per hour) blew in snow from higher elevations and so churned the creek surface that the water became filled with fibril slush. The flowing water was forced into small channels within the slush and flooded out of the main stream at every turn where the banks were low. Moving masses of soft ice carried off two foot-bridges and caused other damage. The stream was carefully inspected during and after the ice dispersed, but no evidence of harm to trout was found.

Anchor-ice formations on rocks at the bases of pools raised the effective height of the pool dams and impounded considerable quantities of water. Encrustations of ice blocked the flow of water into side-channels and turned screens into watertight dams. The result was a gradual decrease in volume of flow. Solar radiation at dawn halted further growth of anchor ice and soon the radiant heat loosened the weak bond between anchor ice and substrate. Clumps of anchor ice broke free, and moved downstream with the current. Impounded water was liberated as the ice breakup progressed and the increasing flow scoured the stream, breaking loose additional quantities of ice and debris. At noon, February 23, a flow of 16.4 cubic feet per second was recorded in the area. The mean flow for this date, according to the discharge record, was 9.8 cubic feet per second. The flow, therefore, must have increased more than double between the early morning minimum and the measured maximum at noon. More typical were daily flows that varied by 4 cubic feet per second (Figure 1). The surge of water disturbed the stream bed enough to carry off many aquatic organisms. This dislodgement proved to be an advantage to trout by making riffle-dwelling insects such as mayflies, stoneflies, and caddiceflies readily available.

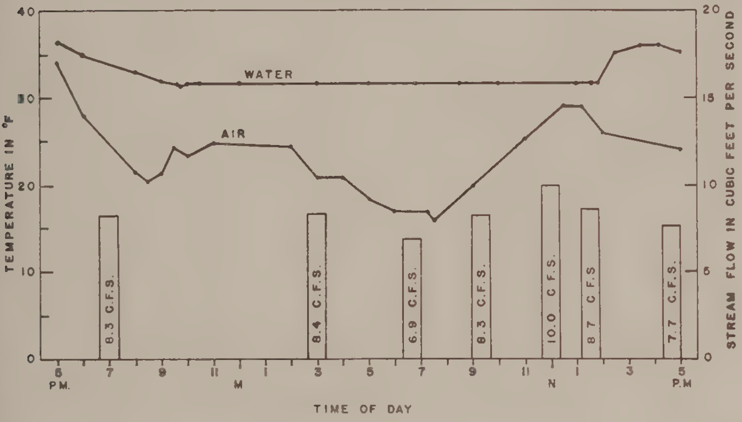

FIGURE 1.—Air and water temperatures and stream discharges recorded in Convict Creek, California, over a 24-hour period on February 25 and 26, 1951.

The presence of subsurface ice kept water temperatures at a 32°F. minimum (Table 2), but as soon as this ice was gone, water temperatures rose regardless of air temperatures or intensity of the sun. Reports of anchor ice lifting gravel, stones, and even large rocks are recorded by Barnes (1906), but these instances occurred in large waterways where suitable conditions enabled the ice to remain attached for several days and become quite thick. Convict Creek cleared daily and, upon one occasion, floating anchor ice had fine gravel imbedded in its base. Seining trout in ice-laden waters was impossible because a slight contact would dislodge the loose clinging ice and fill the net with jagged spicules.

DAILY TEMPERATURE CYCLE

A typical 24-hour period of winter stream and weather conditions is illustrated by data collected February 25 and 26, and presented in Figure 1. Air and water temperatures dropped steadily in the afternoon and evening of February 25. The air reached 32°F. at 6 P.M. and remained slightly below this point during the succeeding 2 days. At 9:45 P.M., the water momentarily dipped to its minimum temperature and colloidal particles appeared. Within 10 minutes, the concentration of these discs was so great that they could be seen within the water. Fine filaments of anchor ice began to form on a rock under observation at 10 P.M. This formation grew visibly for several seconds and, within a minute, appeared on many adjacent rocks. Growth then progressed less noticeably, to form a mat over the stream bed. Colloidal discs disappeared from the water. By 10:30 P.M., anchor ice had become 2 inches thick, and further growth continued until 11 P.M., when a cloud cover moved over the sky. The growth of anchor ice halted temporarily and stream flow, which had been decreasing by impoundment, began to rise slightly. A fine, light snow fell intermittently until 3:00 A.M., when the cloud layer broke up. The snow crystals that fell into the stream formed filmy masses of frazil that trailed downstream. As soon as the cloud cover scattered, anchor ice resumed its growth, air temperatures dropped, and stream flow decreased. These conditions prevailed until sunrise, when the anchor ice had reached a thickness of 7 inches.

Little change was observed between sunrise (6:45 A.M.) and 8:30 A.M., except a slight loosening of anchor ice from the stream bottom and a visible increase in stream flow. The real breakup of anchor ice commenced at 8:30 A.M., causing a rapid increase in volume of flow. At this time, many trout appeared in the stream to feed on the food being carried downstream. Stream flow leveled off shortly after noon. All anchor ice became free from the stream bed by 1:30 P.M. and stream flow then dropped noticeably. After floating clumps of subsurface ice disappeared at 1:50 P.M., the water temperature rose suddenly to 36°F. at 3:30 P.M. After this time trout ceased to feed and both temperatures and flows slowly decreased to 5:00 P.M., thus completing the 24-hour cycle.

ACTIVITY OF TROUT

It is generally assumed that trout are less active during the winter months than in the warmer seasons. Excluding migrations, this condition was found untrue, since trout in Convict Creek were quite active in spite of cold water temperatures. Most of the time, the fish remained under shelf ice, cutbanks, and among willow roots and brush. As the sun took effect upon subsurface ice, trout suddenly appeared in the open stream. Throughout the day, especially as temperatures rose, the fish could easily be observed. In late afternoon, trout seemed to disappear as the temperatures dropped. Very few trout were seen at night, although several fish kept in a live car were observed at all hours. These fish were far from sluggish at night in the freezing, ice-laden water. Frazil and anchor ice usually had to be cleared away to find the trout, but they deftly avoided capture by hand.

No device was installed to check migrant fish but a careful watch was kept at the screening points on the experimental sections. During fall months, brown trout fingerlings nearly always could be found in the enclosed water between the screens and the flashboards. One warm February day with the water at a monthly peak of 44°F. several fingerling brown trout were observed on the concrete apron of the lower screen structure attempting to enter the experimental sections. No such attempts were observed again until late March, at which time the water temperatures rose above 43°F. Two large brown trout tried to enter the sections in late January and early February during a warm spell of weather.

Some trout normally occupied small side channels during summer and fall. Observations indicate that these trout vacated the side channels in early January, frequented them occasionally on warm winter days, and returned from the main stream to reinhabit the smaller channels in late March.

WINTER FOOD SUPPLIES

Winter is the time of greatest abundance of immature aquatic insects, a matter of considerable importance to trout. Besides the usual forms of aquatic organisms common to Convict Creek, an abundance of aquatic oligochaetes [*Helodrilus tetraedrus* (Savigny)] appeared during the months of study. So numerous were these bristle-worms in certain areas that a handful of coarse sand from the stream bottom yielded a dozen individuals. They formed approximately 10 percent of drift and bottom foods available to trout in the winter of 1951.

The emergence of adult insects was a fairly common event throughout the winter, perhaps because the weather was mild in 1951. On December 29, a hatch of blackflies (Simuliidae) took place. Thereafter, on warm days in latter January, mid February, and most of March, when water temperature was 40°F. or more, some blackflies and many midges (Chironomidae) emerged. Adult stoneflies (genera *Nemoura* and *Capnia*) appeared abundantly in late January and sparingly during the remainder of the winter. Besides these aquatic forms, terrestrial dipterans and lepidopterans were found. Mayfly and microcaddis adults (Hydroptilidae) began emerging in late March.

BOTTOM FOODS

Few quantitative riffle bottom samples have been taken under severe winter conditions. Needham (1938) reports a standing crop of 103 pounds per acre in the Merced River in California in February of 1933. Bottom samples taken from the same riffle in August produced an average of 85 pounds per acre. Both of these figures are based upon four samples. Convict Creek, from a series of five samples taken in February of 1942, indicated an average standing crop of 134 pounds per acre.

It is of interest to compare the amount of bottom foods found in winter with those obtained from summer samples in Convict Creek. Over the 5-year period from 1938 through 1942 inclusive, 225 bottom samples were taken in Convict Creek between May and September. Unpublished data indicate that the 5-year average was 109 pounds per acre and the average, annual summer amounts varied from a low of 68 pounds per acre in 1938 to a maximum of 197 pounds in 1942. While the five winter samples taken in 1942 produced an average of 134 pounds per acre and are far too few in number for any adequate comparison with summer food conditions, nevertheless it is evident that the 134 pounds per acre is well above the average of 109 pounds indicated for the five seasons covered. The reasons for greater abundance of bottom foods in winter must be that few aquatic insects emerge in winter and therefore the bulk of them are present in one stage or another.

A comparison of the food organisms found in 11 bottom samples taken in the winter of 1951 and the 5 samples secured in February, 1942, is presented in Table 3. Mayfly nymphs dominated the 1942 samples forming over 53 percent of the 1,865 animals collected, while in the 1951 series other groups were relatively more numerous. Caddicefly larvae, for instance, contributed over 29 percent. Midge larvae made up over 12 percent of the 1951 samples and 18.8 percent of the 1942 collections. Oligochaetes were much more abundant in 1951 when they totaled 139 or almost 12 percent. In 1942 only 79 of these organisms formed 4.2 percent.

Wide differences in both seasonal and yearly abundance of bottom food are indicated in the above figures. The average number of animals collected per square foot in the 1951 winter samples was 107; that for the five taken in February, 1942, was 373 or over three times as many. As was pointed out above, the 1942 summer series of samples indicated an average of 197 pounds per acre and evidently the winter abundance was reflected over the following summer when the measured crop increased from the winter average of 134 pounds to 197 pounds per acre.

The implications of these findings with respect to stocking policies are obvious. Evidently stream populations are highly unstable and subject to vicissitudes similar to those of land animals and plants. The use of arbitrary stocking tables will, we feel, become a thing of the past or they will have to be modified by the development and application of factors to reduce or increase the numbers of fish to be stocked in relation to variable seasonal or annual conditions and fishing pressure.

DRIFT FOODS

A total of 130 organisms was collected in nine samples. As will be seen in Table 4, caddicefly larvae and dipterans occurred in equal numbers followed by mayfly nymphs, oligochaetes, beetles, and stonefly nymphs, respectively. In terms of weight, oligochaetes contributed over 55 percent, mayfly nymphs, 26.5 percent, with the other groups contributing relatively minor amounts.

TABLE 3.—*A comparison of the number and percentage of riffle bottom organisms from Convict Creek in 1942 and 1951 (11 samples, 1951; 5 samples, 1942).*

Group of organisms	January-March, 1951		February 9, 10, 1942	
	Number & stage[1]	Percentage	Number & stage[1]	Percentage
Ephemeroptera	258(n)	21.8	995(n)	53.4
Trichoptera	346(l) 1(p)	29.3	237(l) 1(p) 1(a)	12.8
Diptera	140(l) 2(p) 5(a)	12.4	351(l)	18.8
Coleoptera	151(l) 39(a)	16.0	162(l) 18(a)	9.7
Plecoptera	37(n) 1(a)	3.2	10(n)	0.5
Oligochaeta	139	11.7	79	4.2
Miscellaneous	67	5.6	11	0.6
Totals	1,186	....	1,865	... .

[1] Abbreviations used: l—larvae, n—nymphs, p—pupae, and a—adult.

The greatest number of drifting foods was always found during periods of peak flow. On one occasion, a set made from 11:10 A.M. to 11:25 A.M. contained a large number of insects, while sets preceding and following it by 15 minutes, gave meager returns. The organisms captured in this manner (Table 4), as might be expected, are generally the smaller ones of weak attachment or poor swimming ability. It is conceivable that larger organisms return to the substrate quickly upon being dislodged, while smaller ones may be carried far in the current.

Trout were observed feeding only during and following peak flows. It was thought that, under these conditions, trout might feed only upon the drifting organisms. Data from bottom samples, drift samples, and trout stomachs taken during such periods are grouped for comparison in Table 5. Here it is evident that there was some correlation between availability and ingestion. Caddiceflies were dominant in the four bottom samples concerned, forming 28.3 percent by number, while this group totaled 41.7 percent of foods eaten by 18 trout and 28.5 percent of all drift foods available. Similarly, mayfly nymphs formed 19.4 percent, 23.8 percent, and 31.8 percent, respectively, of the number of bottom, drift, and ingested foods. Comparing these on a basis of weight (Table 5), little correlation is evident.

STOMACH EXAMINATIONS

A few trout were collected by seine, trap, and angling each week for stomach examinations. Analysis of these data shows a marked difference between the winter food habits of brown and rainbow trout (Table 6). Forty brown trout stomachs contained 578 organisms or 14.5 per fish, while 53 rainbow trout consumed 1,337 organisms or 25.2 per fish. Yet, the mean stomach volume for all brown trout was 0.29 cubic centimeters, and that for all rainbow trout was 0.28 cubic centimeters. This difference in numbers of organisms consumed is accounted for by the greater percentage of larger organisms in brown trout stomachs. The rainbow trout ingested many small midge and blackfly larvae, while brown trout consumed proportionately more caddicefly larvae.

TABLE 4.—*Number and weight of organisms taken in 9 drift net samples, Convict Creek, California, February 19 through March 8, 1951.*

Group of organisms	Number & life stage[1]	Percentage by number	Weight in grams[2]	Percentage by weight
Oligochaeta	14	10.7	.139	55.8
Coleoptera	3(l) 1(a)	3.1	.001	0.4
Diptera	29(l) 5(p) 3(a)	28.5	.020	8.1
Ephemeroptera	31(n)	23.8	.066	26.5
Plecoptera	3(n)	2.3	.006	2.4
Trichoptera	37(1)	28.5	.016	6.4
Miscellaneous	4	3.1	.001	0.4
Totals	130	....	.249	....

[1] Abbreviations: l—larvae, n—nymphs, p—pupae, a—adults.
[2] Weight from alcohol.

Over the whole winter period dipterans represented only 12.4 percent of total available bottom organisms (Table 3) but supplied the greatest percentage in numbers of food items eaten (Table 6), both by rainbow (54.9 percent) and brown trout (31.6 percent).

Further analysis indicates a difference in general winter feeding habits as compared to strictly cold water feeding. A comparison of foods ingested in ice-laden water (Table 5) with those taken during the entire winter, December 29 to March 22 (Table 6), denotes a greater cold water consumption of mayflies, stoneflies, and caddiceflies, with more flies (Diptera), beetles, and oligochaetes being ingested during the entire period of study.

A rainbow and a brown trout between 6 and 8 inches long each had two, eyed trout eggs in their stomachs (Tables 5 and 6). This was the only direct evidence of disturbance to spawning beds observed. These fish were taken during extremely cold weather when much anchor ice formed at night. The action of ice in disturbing spawning gravels may have freed these eggs in the current. Scarcity of trout eggs in the stomachs suggests that anchor ice in the winter of 1951 caused slight disturbance to naturally spawned brown trout eggs.

TABLE 5.—*Comparison of fish food organisms from 4 stream bottom samples, 9 drift net samples, and 18 trout stomachs,*[1] *Convict Creek, California, February 19 to March 8, 1951.*

Group of organisms	Percentage by number			Percentage by weight[2]		
	Bottom foods	Drift foods	Ingested foods	Bottom foods	Drift foods	Ingested foods
Trichoptera	28.3	28.5	41.7	12.2	6.4	58.1
Ephemeroptera	19.4	23.8	31.8	5.4	26.5	9.4
Diptera	14.0	28.5	17.2	8.7	8.1	10.2
Plecoptera	3.0	2.3	4.0	11.8	2.4	1.6
Oligochaeta	10.7	10.7	2.7	60.6	55.8	9.8
Coleoptera	22.0	3.1	1.3	1.2	0.4	1.5
Miscellaneous	2.6	3.1	1.3	0.1	0.4	9.4

[1] Stomachs from 9 brown and 9 rainbow trout.
[2] All weights from alcohol.

Observations and stomach examinations indicate that low water temperatures did not limit the feeding activity of trout in Convict Creek. In over 100 healthy specimens of trout taken, only one rainbow

TABLE 6.—*Organisms found in stomachs of 40 brown and 53 rainbow trout, Convict Creek, California, December 29 through March 22, 1951.*[1]

Group of organisms	Brown trout		Rainbow trout	
	Number[2]	Percentage by number	Number[2]	Percentage by number
Oligochaeta	27	4.7	46	3.4
Coleoptera	17(l) 26(a)	7.4	45(l) 7(a)	3.9
Diptera	143(l) 14(p) 26(a)	31.6	712(l) 12(p) 10(a)	54.9
Ephemeroptera	65(n) 2(a)	11.6	187(n) 1(a)	14.1
Plecoptera	14(n) 2(a)	2.8	8(n) 2(a)	0.8
Trichoptera	215(l)	37.2	288(l)	21.5
Miscellaneous	27	4.7	19	1.4
Total	578	....	1,337	....

[1] Brown trout size—range was 8.3 to 20.7 centimeters (total length), with a mean total length of 14.3 cm. Rainbow trout ranged in size from 8.0 to 31.7 centimeters and had a mean total length of 14.5 cm. Total length as used here means length from tip of snout to end of caudal rays.
[2] Abbreviations used: l—larvae, n—nymphs, p—pupae, a—adults.

and three brown trout had stomachs that contained only a trace of food or none at all. Trout were observed feeding at all water temperatures. On several occasions trout were taken by hook and line (using a single egg or an aquatic bristle worm) in ice-laden water at a temperature of 32°F. Surface feeding was observed whenever aerial insects were present and usually at a water temperature of 35°F. to 42°F. The regularity of trout feeding during periods of low water temperatures raised the question of digestive rates. Hess and Rainwater (1939) reported that brook trout digestion was almost at a standstill in 1.9°C. (35.4°F.) water. A superficial experiment was conducted at Convict Creek by the senior author, in which several trout were force-fed mayfly and stonefly nymphs, and aquatic oligochaetes, then returned to a live car in the creek. Examinations of the trout stomachs at various intervals indicate that at least 50 percent of the total food fed to each fish was digested in 14 hours at temperatures between 32°F. and 35°F.

TROUT MORTALITY

Winter has long been suspected as the season of greatest trout mortality. Needham, Moffett, and Slater (1945) found that overwinter decrease in brown trout in Convict Creek averaged 60 percent over 4 years in uncontrolled stream sections. This loss was attributed to the severity of winter conditions, principally drifting snow and ice. Needham and Slater (1944) report the smothering of several hundred trout by the collapse of a snowbank into a rearing pond.

Because there was light snowfall in the winter of 1951 in the Convict Creek area, there was no opportunity to study the effects of this factor. A type of winter mortality occurred during early January in which trout of all sizes were victims of cold weather. On January 10, following 3 days of low temperatures, 63 trout were found stranded on damp rocks at the bottom of shallow pools in a flood control bypass. Heavy nightly subsurface ice formations at the flood control structure, combined with incomplete daily thawings, had progressively diminished the flow of water into the bypass. In the early morning hours of January 10, water had ceased to flow into the bypass and the fish were suffocated where the water drained into the porous substrate. Layers of surface ice insulated the fish from freezing. This type of mortality was not confined to the bypass. Several days later, after warm winds and sunshine had melted surface ice from the stream, other dead trout were observed in similar situations, some in natural side channels as far as 1½ miles above the Experiment Station. No other cause of mortality could be directly attributed to winter conditions in the present study. Predation was unimportant at Convict Creek, since no predatory birds or mammals were seen during the study nor were their tracks or signs found. A 24-inch female brown trout was found to have eaten another trout about 6 inches long.

Throughout the winter, very few trout seen or captured were in poor condition. However, dead and emaciated trout recovered within the experimental sections between November 7, 1950, and April 21, 1951, totaled 7 brown and 46 rainbow trout. Thin, weakened fish, carried downstream by the current, were retrieved dead or dying at the screen structures. The higher percentage of hatchery rainbow trout found is indicative of their greater susceptibility to winter emaciation than wild brown trout. This mortality is peculiar in that it never occurred in periods of freezing weather. Between January 1 and March 15, only 11 dead trout were picked up at the screens, and these appeared only in the warmest weather. Possibly this is the result of a lower metabolic rate in colder water.

If any line is to be drawn between advantageous and detrimental winter conditions, it must be one of degree. The winter experienced during this study is considered mild because of the lack of snow. Low air and water temperatures occurred (Table 2) but were probably shorter in duration than in winters having more severe climatic conditions. Generally, trout fared quite well, for ice conditions that caused a small initial winter mortality, later offered fish cover and food. It is probable that lower temperatures, more continuous cold weather, heavy snowfalls, or a combination of these would have a more drastic effect on fish and other stream life.

OPERATIONAL HAZARDS OF EXPERIMENTAL SECTIONS

The year 1951 marked the first winter operation of the Convict Creek Station. The main purpose was to determine over-winter survival rates of wild and hatchery trout planted in experimental stream sections. It was found impossible to pass stream-borne ice and slush through the screens and, when the water temperature dropped to 32° F., ice formed in the screen meshes creating dams which forced the water to flow over or around water control structures and channels. Although it was observed that trout were reluctant to migrate any distance when water temperatures were below 42° F., it was nevertheless apparent that there existed abundant opportunity for escape of fish from the experimental sections during periods of overflow. Strong winds greatly increased the flow of Convict Creek by increasing out-flow from the lake 2 miles above the station, and also caused formations of heavy clumps of spray ice to form around the screen structures. Surface ice often froze screens solidly in the concrete slots of the flumes, making it impossible to remove them for cleaning. High winds frequently blew heavy quantities of leaves into the stream which plugged screens before they could be removed, and caused overflow around or over them.

In spite of these difficulties when the fish were recovered from the stream sections during the last week of April, 1951, approximately 50 percent of the marked trout stocked in November, 1950, had survived.

ACKNOWLEDGMENTS

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DISEASES AND PARASITES OF THE SEA LAMPREY, *PETROMYZON MARINUS,* IN THE LAKE HURON BASIN

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Abstract

Sea lampreys from the Lake Huron basin carried no external parasites and showed a fairly low degree of infection by internal parasites. The material examined represented three life-history stages of the sea lamprey. Recently transformed downstream migrants (215 specimens) harbored only nematodes belonging to the genus *Camallanus.* The percentage of infection was 2.3. Active feeders from the lake (29 lampreys) revealed the highest degree of parasitism (31.0 percent) with the following parasites present: *Echinorhynchus coregoni* Linkins; *Triaenophorus crassus* Forel; and *Camallanus* sp. Among the 257 sexually mature upstream migrants (14.8 percent infected) *Echinorhynchus coregoni* and *E. leidyi* Van Cleave were the most common. Only occasional nematodes and cestodes were found, which fact indicates a failure of the lamprey to carry these parasites to the end of its natural life. Of the parasites observed, only the nematodes gave evidence of serious damage to the host. The study suggests that the role played by parasites in the natural control of the sea lamprey in its new habitat in the upper Great Lakes is of minor importance.

Introduction

The sea lamprey, *Petromyzon marinus,* can be added to the list of animals which have been introduced or have invaded a habitat where endemic forms offer little or no control by competition, disease, parasitism, or predation. Without a natural or biotic control its numbers have increased to a point where the animal, being parasitic itself, has visited such destruction upon the fisheries of the Great Lakes that it will have few equals in history.

To combat this recognized menace effectively all phases of its life history and biology must be explored with consideration given to any point that appears vulnerable to an attack. This study represents one phase of a comprehensive program of such investigations currently being carried on by the U. S. Fish and Wildlife Service's Great Lakes Fishery Investigations. Presented herein are data relative to the incidence of diseases and parasites among samples of the sea lampreys at various life-history stages and the comparative degree of infection among spawning migrants in 3 consecutive years.

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MATERIAL AND METHODS

The majority of the sea lampreys collected for this study were captured in experimental control devices operated in various streams in the northern part of the Lower Peninsula of Michigan. A total of 257 sexually mature upstream migrants were obtained in 1949 and 1950 from a weir and trap installed in the Ocqueoc River, Presque Isle County, Michigan. Two hundred fifteen downstream migrants (recently metamorphosed) were taken at random from runs captured in an inclined-plane trap operated in the Carp Lake River, Emmet County, and in fyke nets fished in the Ocqueoc River in 1950 and 1951. In addition, 29 actively feeding sea lampreys became available during the period of study. These lampreys were attached to fish taken in trap nets set in the inshore waters of northern Lake Huron. Comparative data on the degree of parasitization of spawning migrants captured in 1948 in this area have been taken from Applegate (1950).

Inasmuch as organizational effort was almost completely confined to the operation of experimental control devices during the period of upstream migration, it was necessary to preserve the material collected until the time of examination. Quick-freezing and holding in cold storage proved to be satisfactory. For the most part, the downstream migrants and the active feeders from the lake were held alive until examined. At most this period of holding did not exceed 3 days.

Each animal was examined for external parasites, wounds, or any abnormality which might be revealed under macroscopic observation. The complete digestive tract was then removed for examination and the body cavity and internal organs were carefully inspected. In the preparation and preservation of the material taken from the sea lampreys, laboratory techniques commonly prescribed for the individual parasites were followed. Some tumor-like growths and abnormal organs were sectioned whereas others were macerated and examined microscopically.

PARASITIZATION OF SEA LAMPREYS AT DIFFERENT LIFE-HISTORY STAGES

The sea lamprey begins its parasitic life after an apparently harmless existence as a blind, toothless ammocete in the mud beds of its parent stream. It appears to be an exceedingly healthy individual, and tends to remain comparatively so until the physical degeneration begins which subsequently results in its death after spawning. In the material examined no recognizable bacterial, virus, or sporozoan infection was found.

Although an occasional specimen revealed external body wounds which were obviously of mechanical origin, none exhibited secondary infections. No significant incidence of developmental or structural abnormalities was found. One downstream migrant had a body which appeared to end posteriorly at the midpoint of the second dorsal fin. By comparison, its body should have been approximately 25 percent longer. Surprisingly enough, this abnormality did not seem to impair the locomotion of the animal to any great extent.

In general, the sea lamprey population in the Lake Huron basin has a comparatively light infection and a fairly uniform composition of internal parasites. The most common parasites are adult Acanthocephala which inhabit the digestive tract. Two species were found, *Echinorhynchus coregoni* Linkins and *E. leidyi* Van Cleave.[1] *E. coregoni,* by far the most common, was found throughout the entire length of the digestive tract with a few individuals located almost at the anal opening. In no specimen was the infection heavy enough to be considered harmful or severe. The greatest number of Acanthocephala found in a single sea lamprey was 15; another sea lamprey contained 8; three had 7; and the remaining lampreys had from 1 to 4 parasites, most commonly 1 or 2. In a sample of 100 sea lampreys from the 1948 spawning run examined by Applegate (1950), only *E. coregoni* was found, and in no case did a single lamprey harbor more than three of the parasites.

Very little is known of the life histories of *E. coregoni* and *E. leidyi* and the mode of infestation is not at all obvious, especially in view of the mechanics involved in the feeding behavior of the sea lamprey. The two species often occur in mixed infections and the adult *E. coregoni* has been commonly reported from the coregonid and other freshwater fishes of North America and Europe. Although the hosts of the adult worms are believed to be preferred prey for the sea lamprey, the transfer of adult Acanthocephala appears unlikely. It would seem that an encysted stage must become available to the sea lamprey. H. J. Van Cleave[2] states that some species of Acanthocephala must reach a certain stage of maturity in their anthropod host before development in the fish host will proceed normally. Otherwise, they tend to encyst in the mesenteries of the fish. They could be taken by the lamprey directly in this encysted stage, or possibly by ingestion of amphipods and copepods.

Of the total number of sea lampreys examined, only three individuals harbored cestodes. An upstream migrant contained a single specimen, and two individuals captured in Lake Huron contained a total of three specimens. With the possible exception of one which was found embedded in a small cyst-like growth, these cestodes were identified as *Triaenophorus crassus* Forel.[3] The specimen from the abnormal growth was almost completely disintegrated except for portions of the scolex but the remains appeared to be those of *T. crassus.* The second juvenile stage, or the plerocercoid larva of *T. crassus* is frequently found encysted in the flesh of the coregonid fishes (Van Cleave and Mueller, 1934). Thus the mode of infestation appears fairly obvious. It is believed that this cestode would not reach sexual maturity in the sea lamprey, an unnatural final host. In the sample taken during the 1948 run, Applegate (1950) found a plerocercoid larva of *T. crassus*. He also found a single, immature specimen of *Abothrium* sp. and the unidentifiable remains of another cestode.

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[1] Identified by Dr. H. J. Van Cleave of the University of Illinois.

[2] Personal communication.

[3] Identification verified by Leonard N. Allison, Fisheries Pathologist, Michigan Department of Conservation.

It appears that nematodes produce the most serious pathological disturbance. In all lampreys which contained them, a tumor-like growth or a severely damaged organ existed. Unfortunately, only females belonging to the genus *Camallanus* (identified by L. N. Allison) were found. Positive identification of the species was not obtained.

In addition to the general observations recorded above, the mode and degree of infection and/or parasitization differed among the various life history stages as follows.

Downstream migrants.—In addition to the 215 newly transformed lampreys (Table 1), three selected specimens were examined that had a greatly swollen area just posterior to the branchial region. Dissection revealed that two of the lampreys had severely infected livers while the third had a large tumorous growth one-half inch long and one-fourth inch in diameter, attached to the gonads just behind the liver. Both livers were greatly enlarged—one approximately four times and the other about three times normal size. The livers were vacuolated and of a homogeneous consistency. The only portion of either liver which appeared normal was the very tip of the lobe. A nematode *(Camallanus* sp.) was removed from one of the livers and from the tumerous growth, but nothing was found in the other liver.

Five additional individuals with infected livers were discovered in the sample of 215 young sea lampreys. All were comparable in appearance to those described above except that the diseased organs were not as severely enlarged. Four of the abnormal livers contained one specimen each of *Camallanus* sp. Nothing was found in the other. Two more young lampreys were found with tumor-like growths. In one specimen a small cyst-like growth attached to the wall of the body cavity yielded no causative agent while a fairly large gelatinous mass found on the outer intestinal wall of the other lamprey contained a nematode *(Camallanus sp.)*. Thus of the 215 downstream migrants examined, 5 or 2.3 percent were parasitized, while 2 more contained abnormalities which were probably the result of parasitism.

Upstream migrants.—Of the 257 sexually mature, upstream migrants examined, 123 were collected in 1949 and 134 in 1950. No external parasites were found, but 22, or 17.9 percent of the 1949 run and 16, or 11.9 percent of the 1950 run contained one or more internal parasites. As was mentioned previously, *Echinorhynchus coregoni* was by far the most common parasite present. Only one cestode and one nematode were found in the entire 1949 collection of spawning migrants (Table 1). The cestode, *Triaenophorus crassus,* was found in the digestive tract of one lamprey and in another individual the nematode, *Camallanus* sp., was in the periphery of a large (1 inch long and ½ inch in diameter) tumor which was attached to the gonads just posterior to the liver. A third specimen had a similar growth, also attached to the gonads, for which no causative agent was determined. Similarly, nothing was found in 2 small (¼ inch in diameter), colorless, cyst-like growths on the outer intestinal wall of another sea lamprey.

TABLE 1.—*Percentage of sea lampreys infected with internal parasites and abnormal growths with no detectable causative agent.*

Stage and date of collection	Number examined	Percentage parasitized	Percentage parasitized			Percentage with abnormal growths
			Acanthocephalans	Nematodes	Cestodes	
Upstream migrants						
1948[1]	100	20.0	17.0	....	3.0	....
1949	123	17.9	16.3	0.8	0.8	1.6
1950	134	11.9	11.9	....	....	0.7
Lake feeders						
1950—51	29	31.0	13.8	10.3	6.9	3 5
Downstream migrants						
1950—51	215	2.3	....	2.3	....	0.9

[1] Applegate (1950).

The 1950 sample of spawning migrants was less severely infected than either the 1949 sample or the collection examined by Applegate (1950) from the 1948 run. Parasitization was restricted solely to Acanthocephala and only one individual with a diseased organ was discovered. In this specimen the liver exhibited an abnormality which was generally comparable to those found in the downstream migrants. It was slightly enlarged and covered with small, whitish nodules. Sectioning failed to reveal any parasites, but it appeared likely from comparisons with similar diseased organs among downstream migrants that a nematode was the causative agent.

Actively feeding lampreys from the lake.—Only 29 actively feeding sea lampreys collected directly from the lake became available during the study period. Of the group, 9 or 31 percent contained parasites or the identifiable remains of a parasite. Four or 13.8 percent of the individuals carried *Echinorhynchus coregoni;* 3 or 10.3 percent contained nematodes, *Camallanus* sp.; and 2 harbored cestodes, *Triaenophorus crassus.* One of these cestodes was mentioned previously as embedded in a cyst-like growth and as being almost completely disintegrated. One other lamprey contained two cestodes.

The nematodes, as before, were found in tumor-like growths. Along with the growth which yielded a nematode in one sea lamprey were two more growths that were comparable in every way to those containing the nematodes. One was located on the outer intestinal wall and the other was on the wall of the body cavity. These two growths yielded three unidentifiable fragments which appeared to be the walls of cysts formed by some animal which had subsequently disintegrated. Microscopic examination of the fragments failed to reveal any organization of tissue.

Actively feeding lampreys in aquaria. — Sea lampreys confined in 55-gallon glass aquaria show a fairly high degree of susceptibility to infection from fungus, *Saprolegnia parasitica* Coker, and to the ectoparasitic protozoan, *Ichthyophthirius multifilis,* which is commonly referred to as "the itch." Only one outbreak of "the itch" occurred in more than 14 months of continuous operation of the aquaria. The disease is reported to be common and widespread and to attack many species of fish, especially those of ponds. The attack by *Ichthyophthirius multifilis* was severe and at least five aquarium-held lampreys died as a result of heavy infection. Commonly prescribed methods of control (Davis, 1947) have proved effective in combating both diseases. Neither of the diseases was found on any of the individuals taken from the "wild."

CONCLUSIONS

Three separate patterns of parasitism were encountered in the three life-history phases of sea lampreys examined (Table 1). Although the number of active feeders from the lake was too small to yield conclusive information for that group, there is evidence for a definite trend in the pattern of parasitization as the lamprey passes through its several stages of existence. A very small percentage of the downstream migrants were parasitized and then only by a single species of nematode. In the second group, the active feeders, a relatively high percentage (nearly one-third) of the sample was parasitized and representatives of cestodes and nematodes as well as acanthocephalans were encountered. The third group (upstream migrants), revealed a sharp decrease over the active feeders in the percentage of individuals parasitized. However, the percentage of upstream migrants infected with Acanthocephala was comparable to the percentage in active feeders. The failure of the sea lamprey to carry the majority of the nematodes and cestodes to the end of its natural life brings out one of the most interesting points of the study.

There are at least two means whereby cestodes encountered by the sea lamprey may disappear before the time of upstream migration. One possibility is that since the sea lamprey is an unnatural final host, the worm dies and is passed out. The other possibility lies in the fact that the sea lamprey ceases to feed prior to ascending the streams to spawn. With the cessation of feeding, physical degeneration begins which almost immediately affects the gross and microscopic anatomy of the digestive tract. The intestine is usually a fraction of its normal size and is nearly empty at the time of upstream migration. It is believed that many of the tapeworms disappear during this period. Furthermore, the almost completely disintegrated remains of the cestode found in a small cyst-like growth may well indicate the mode of disappearance. Comparable growths were discovered in which no causative agent was found.

The situation is somewhat different in the nematodes. They are probably the most important of the parasites, causing the most serious pathological disturbances in the sea lamprey. For the most part they are acquired while the animal is still inhabiting its larval beds. It also seems that this parasite has a preference for invading the liver. The condition of this organ resulting from the invasion is such that in all cases it appeared incapable of functioning properly and could result only in the ultimate death of the sea lamprey. If the nematodes attack the gonads, kidney, or wall of the body cavity, the so-called tumerous growths result.

The tumors and cyst-like growths can possibly be compared to a fibrosis or to an adventitious cyst. Although their presence may be harmful or painful to the sea lamprey, their actual pathological effect is questionable.

It appears that the role played by disease and parasitism in the natural control of this animal in the Great Lakes is so insignificant that it is of no importance. There are no indications derived from this study of any natural control arising from this source in the near future.

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Progress Report On The Sea Lamprey Program

By Dr. James W. Moffett
Chief of the Great Lakes
Fishery Investigation

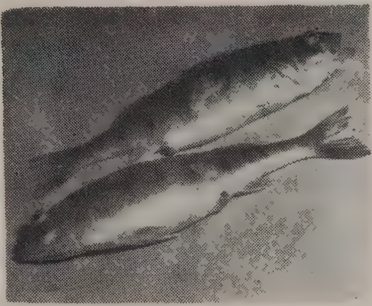
Prior to the establishment of the sea lamprey investigation as part of Great Lakes Fishery Investigations in October, 1949, the Fish and Wildlife Service had been able to carry out only scattered and short-term studies of the problem. Since that time great progress has been made in the organization of a long-term program for the development and testing of methods of controlling this parasite and operations have actually been started on the important phases of that program.

We have added 35 persons to the staff of Great Lakes Fishery Investigations—most of them trained biologists. In that group is included the country's foremost authority on the life history and habits of the sea lamprey. An enlarged central office has been established in Ann Arbor, Michigan, and in order to place trained observers as near as possible to the "trouble centers" of the Great Lakes, field stations have been set up at Hammond Bay, near Rogers City, Michigan, on Lake Huron; Marquette, Michigan, on Lake Superior; and Sturgeon Bay, Wisconsin, on Lake Michigan. The first named of these stations is the operating headquarters for the sea lamprey work, but the staff of the other two stations will contribute to special phases of the sea lamprey studies.

The sea lamprey investigations may be divided broadly into the following phases: development and testing of control devices and procedures, including the accumulation of reasonably exact data on costs of installation and operation of various devices; extension of studies on the life history and habits of the sea lamprey with a view toward determining better the vulnerable stages of the life history; surveys of streams to ascertain the distribution of sea lamprey runs, the extent of available spawning grounds and larval habitats, . . . ; studies of species subject to attacks by sea lampreys to learn the incidence of attacks and the effects on abundance.

Control Devices and Techniques

Physical Barriers — Inasmuch as Mechanical devices, weirs, traps, dams, ... for the blocking and/or capture and destruction of spawning-run sea lampreys at the time of their entrance into streams tributary to the Great Lakes constitute the only means as yet proven effective for controlling the sea lamprey, our first year's program is concentrating on that type of structure. The major center of activity for this work is the northern part of the lower peninsula of Michigan where weirs and traps have been installed in each of the 12 streams in an experimental control zone extending from Waugachance Point at the west end of the Straits of Mackinac to Alpena, Michigan. These structures are making it possible to capture the entire spawning run on this stretch of shore. As of June 9, 20,251 spawning migrants have been captured in the area.



Heavy Scaled Perch are Also Marked by the Sea Lamprey

On Lake Superior a weir is in operation on Pendill's Creek, a tributary of Whitefish Bay, but because of the colder water and the consequently later run, only three lampreys have been captured.

Through a cooperative arrangement with the Wisconsin Conservation Department, 5 weirs are in operation in streams of that state tributary to Lake Michigan. Materials and technical advice on the construction of these structures were supplied by this Service. Through June 1 the Wisconsin weirs took 13,406 sea lampreys.

Another and similar cooperative agreement with the State of Indiana lead to the installation of a weir in Trail Creek, a tributary of southern Lake Michigan. Many lampreys were taken but damaging floods necessitated the weirs removal.

These numerous weirs are serving two purposes. First, they are achieving a certain measure of control, particularly in the section of shore where all streams are blocked. Second, they are providing information and experience on the type of construction needed under various stream conditions and are yielding data on the cost of installation and operation of the various structures.

In cooperation with the Michigan Department of Conservation we are experimenting in the Black River, a tributary of northern Lake Michigan, on the possibility of using low barrier dams to block spawning-run sea lampreys but at the same time permit the free upstream movement of rainbow trout. This type of structure has the advantage of requiring little attention and hence of having a low cost of operation. Early reports on this barrier dam are highly encouraging.

As an adjunct of studies of barrier dams, it is important to know the fate of spawning-run lampreys that find their upstream movement blocked and are forced to return to the lake. We have accordingly initiated an experiment in which more than 3,000 sea lampreys were tagged in the mouth of the Cheboygan River, a stream containing an impassable dam a short distance above its mouth. These lampreys are being recovered by fishermen and in our own structure in neighboring streams.

As a preliminary to a proposed early extension of our previously mentioned control zone to include all of the United States shore of Lake Huron and part of northern Lake Michigan and the possible ultimate extension of these zones throughout the Great Lakes, engineers of this Service are conducting studies to determine the type of construction and the approximate cost of physical barriers in streams characteristic of the Great Lakes. Information from these engineering investigations will be used for the estimation of the total cost of a control program based entirely on physical barriers.

Other Control Structures—In view of the high construction, maintenance, and operational cost of physical barriers, we plan to check closely on the possible usefulness of other types of barriers. To carry out this highly specialized and technical work, we have let an engineering contract for the development of electric, sonic, light, and electro-magnetic devices that may serve to block or destroy spawning-run migrants or kill young sea lampreys enroute downstream to the lake.

We plan also to install and test a commercially available electric screen which the manufacturer offers to guarantee as effective for the blocking of spawning-run lampreys without harm to or interference with the movements of fish.

Introduction of American Eels—In aquarium experiments conducted by staff members American eels have proven themselves to be predators on larval sea lampreys. We plan experiments in natural streams to determine whether the introduction of eels might prove useful as a control measure.

PROGRESS REPORT

These experiments are to include observations on the effects of eels on native fish as well as sea lampreys.

Studies on the Sea Lamprey

These investigations are designed to gain information on the life history, habits, and physiology of the sea lamprey that might contribute toward the development of more effective control methods. Some of this work is being carried out by our own staff members and some through cooperative arrangements with universities.

At Cornell University we are maintaining a fellowship under which a student (with expert faculty guidance) is investigating the biology of the sea lamprey in certain New York lakes to which it is native. It is hoped that this study may reveal enemies, parasites, and other natural controls.

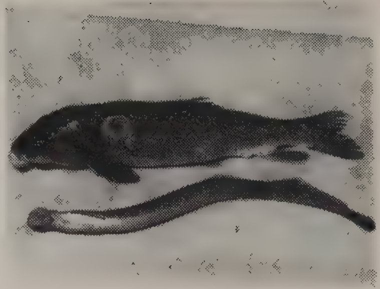
Under a similar arrangement at the University of Wisconsin, a student is engaging in research designed especially to learn the means by which the sea lamprey finds its prey (whether by smell, sight, . . .). Reactions to numerous types of stimuli are to be tested.

We have made further use of the expert knowledge of university faculty members by engaging for the summer the services of a staff member of Ohio State University. This man will concentrate on larval lampreys—type of habitat, factors of distribution and abundance, and the development of quantitative methods of sampling. This information will be most valuable in the event methods are developed for the destruction of larval lampreys in mud flats.

Facilities are being prepared at the Hammond Bay Fishery Laboratory for experiments on the toxicity of various substances to young lampreys. The problem here is to discover a specific toxicant and methods of applying it in natural streams so as to destroy larval lampreys with a minimum of damage to fish.

Counts continue to be made and biological data collected on sea lampreys taken in weirs in order that we may be able to determine immediately any significant change in the numbers in the runs and in the lengths, weights, and sex ratio . . . of lampreys.

Stream Surveys



Lampreys Are Taking Heavy Toll of all Species of Suckers

Two fully equipped stream survey parties of four men each are now in the field for the purpose of examining all streams tributary to Lake Superior on the United States side and streams flowing into Lake Michigan on the south shore of the Upper Peninsula of Michigan and in the upper part of Wisconsin. The objectives of these survey parties include an appraisal of the current distribution of lamprey spawning runs, a cataloging of streams in which runs might become established, the estimation of the extent of spawning grounds and habitat for young sea lampreys, and the measurement and study of possible sites for weirs and other control structures. This work will be assisted by spot checking by staff members of the Marquette and Sturgeon Bay field stations.

Studies of Fish Attacked by the Sea Lamprey

Although seemingly every species of fish in the upper Great Lakes is subject to attack by the sea lamprey, and damage by that parasite to whitefish, suckers, walleyes, . . . is increasing to an alarming extent, the lake trout is by far the species that has suffered the greatest harm to date. Annual losses to fishermen as the result of decline in the production of this species in Lakes Huron and Michigan can be estimated conservatively as close to 2½ million dollars. Only in Lake Superior is the lake trout still reasonably plentiful and even there predation by sea lampreys appears to be increasing.

Because of the importance of saving the lake trout in Lake Superior and of attempting the early rehabilitation of the stocks in Lakes Huron and Michigan, we have assigned a full-time biologist to the investigation of the species with particular reference to its relationship to the sea lamprey. This biologist has drawn up a full program of research and has started work on certain phases of it. He is assisted by other staff members including those at field stations. Biologists at the Marquette station are now carrying out observations on the incidence of scarring of lake trout and other species by the sea lamprey.

The drastic decline in the production of lake trout has led to such shifting of fishing pressure to other species as to threaten them with overfishing. In recognition of this danger, we are keeping close watch on those fisheries both by careful statistical studies of trends of abundance and by direct biological investigation. The staff at Sturgeon Bay, Wisconsin, for example, is devoting much attention to the vitally important fisheries of Green Bay, in which area fishing intensity has increased tremendously.

Specifications and plans have been completed for a new 60-foot vessel, construction of which is scheduled to begin in the immediate future. When this boat is placed in operation it will be possible to study certain aspects of the sea lamprey's life cycle on which only fragmentary information is available now. It will be possible also to experiment on possible methods of capturing and destroying lampreys during their lake life, especially in the fall and winter when they appear to be concentrated off the mouths of streams.

The vessel will permit us further to conduct test-netting as a check on the abundance of lake trout and other species and to collect much needed data on the biological, physical, and chemical conditions in lakes that affect the distribution and abundance of lake trout and other fish.

International and Interstate Cooperation

The Great Lakes Sea Lamprey Committee, now in existence for several years, has served as a means of coordination research and control activities by this Service. the Great Lakes States, and the Province of Ontario. The Chief of Great Lakes Fishery Investigations serves as chairman of the Committee.

Despite the usefulness of the Committee as a general coordinating body, a more detailed coordination and integration of activities than can be had through the Committee is needed to effectuate the type of cooperative project of which numerous examples were cited earlier in this report and which are planned for subsequent seasons. We have accordingly held seperate conferences with officials of the Province of Ontario and of the States of Michigan and Wisconsin in which numerous specific questions of cooperation have been discussed and many solved. Participation by Michigan and Wisconsin in the sea lamprey program is greatly restricted by the limited funds allotted to that work.

(Reprint from The Fisherman, October, 1950 Issue)

The Study and Interpretation of Fish Scales

● **By James W. Moffett, Ph.D.,** *(University of Michigan)*
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Few persons are aware of the amazing amount of valuable information that is now being derived from studies of fish scales, and of how the knowledge so gained is used in conserving our fish supply.

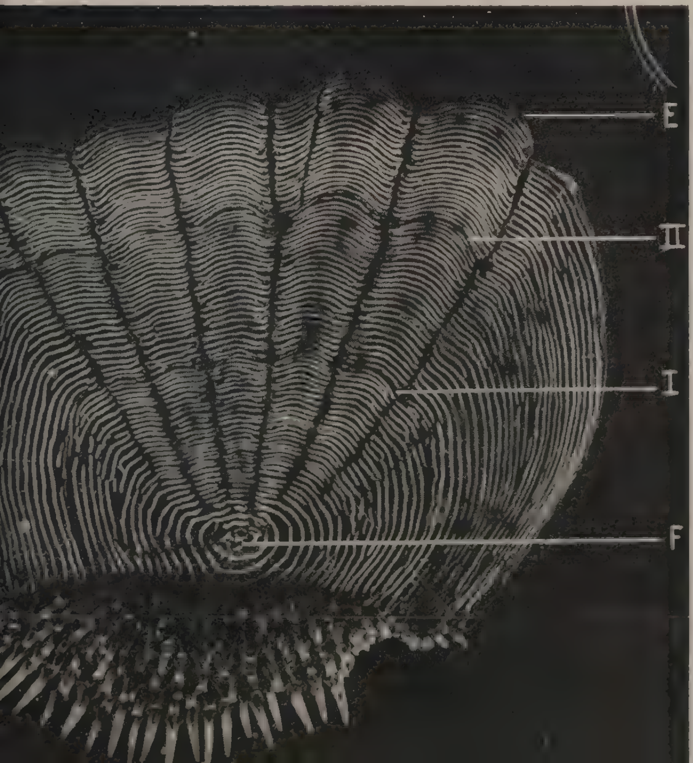
Scale readings disclose growth rate and age, and prove that a small fish is not necessarily young. Such studies help determine average longevity, suitability of various fish to a given water, the effects of growth on varying population densities, and the best rates of harvest.

You will enjoy this enlightening article.

●

From the time of the discovery of the microscope, fish scales have been objects of study and deliberation. Leeuwenhoek, the pioneer Dutch microscopist, found and described eel scales in 1686. He conjectured from their sculpturing that the circular lines on the scales might be records of age. Réaumur, in 1718, believed that the concentric lines on scales indicated different degrees of growth.

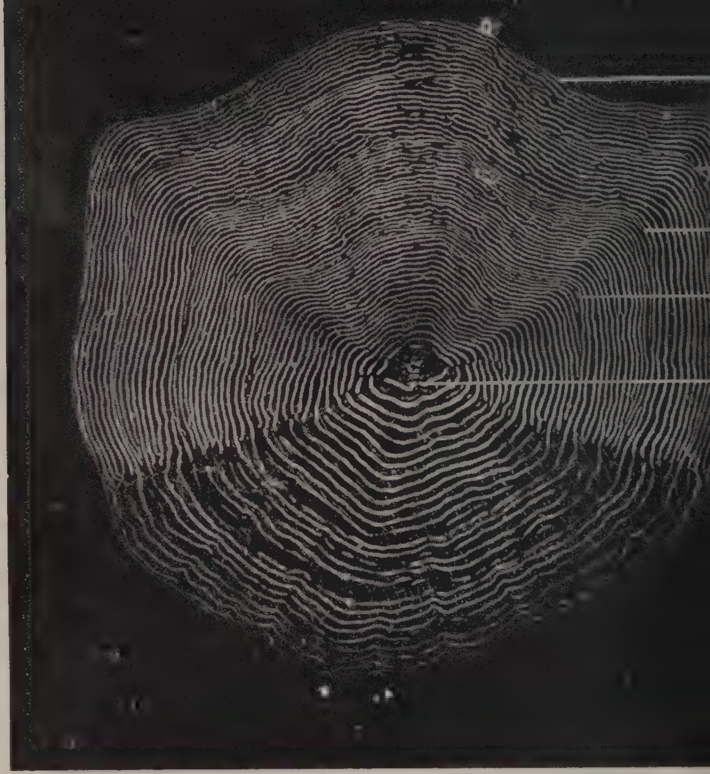
Photomicrograph of Blue Pike Scale. Collected from Erie, Pennsylvania, October 2, 1951. 7.8 inches long. F = focus; I, first year annulus; II, second year annulus; E = edge of scale.



Many other investigators pondered the matter of scale sculpturing in relation to age of fishes throughout the nineteenth century, but none of them did the experimental work necessary to test the idea. Had it not been for an error in interpretation of growth zones, a German, Hintze, would have validated the scale method in 1888 from his study of the scales of carp of known ages. It remained for Hoffbauer, another German, in 1898 to test critically the scale method of age determination. Hoffbauer's findings resulted in the widespread utilization of fish scales as dependable indices of the ages of many fish species. Three years later, a German named Walter first announced the relationship between the relative length and width of a growth zone on a scale and the relative intensity of body growth. As it evolved from these basic concepts, the scale method became a useful tool in life-history studies of most of our important food fishes throughout the world.

Fishes are cold-blooded animals which live and grow at a rate controlled to a certain extent by the temperature of the water they inhabit. They also grow at a rate commensurate with, among other things, their food supply and the density of the population in which they live. Consequently, their growth is a reflection of environmental influences. Most fishes are covered with scales which are arranged in rows and which overlap each other like shingles on a roof. As a fish grows in length and girth its scales also increase in size so as to keep the fish's body covered and protected against injury. The scales grow proportionately to the length of the fish and stand in such a relationship, with minor exceptions, throughout the fish's life.

Fish scales are formed and are retained in small skin pockets. These pockets are lined with cells which produce the material composing the scale substance. If a scale is lost or knocked off, a new one is formed which consists of a clear, smooth plate approximately the size of the lost scale. This scale then resumes the normal type of growth. Scales are laid down in such a manner that concentric rings are conspicuous scale features. The relative spacing of the concentric rings reflects the rate of growth of the fish. A rapidly growing fish will form rings in its scales that are uniform and rather widely spaced. As the growth rate slows down, these concentric rings are much closer together and when



PHOTOMICROGRAPH OF LAKE HERRING. Collected from Green Bay, Lake Michigan, August 20, 1951 8.3 inches long. F = focus; I first year annulus; II second year annulus, III third year annulus; E = edge of scale

growth practically ceases, as it does in winter, the rings are incomplete, rough and closely appressed. It is the line of discontinuity between such "winter marks" on the scales and the pattern formed when more rapid growth is resumed in the spring, that indicates a fish's anniversary. Typical annuli are shown on the accompanying photomicrographs of scales. By counting the number of these "winter marks" or annuli, the age of a fish can be determined.

We have noted that in most fish the scales grow approximately in proportion to the body. It follows then, that given the length of a fish at the time it is caught and the distance from the center (focus) of a scale to its border and the distance from the focus to each "winter mark," the length of the fish at any or all anniversaries during its lifetime can be calculated. This basic fact is of great importance in the study and management of fish populations.

The question has undoubtedly come to mind regarding the problem of age determination in fishes which have no scales. Many fishes, scaled and scaleless, show "winter marks" or recognizable annular rings in their bones. Favorite bone structures preferred for age determination are ear stones (otoliths), vertebrae, gill-cover bones, and fin spines. Bone structures are usually cut into thin sections and examined microscopically for the characteristic annular marks. Such studies are often conducted as a partial check on the validity of the scale method of age determination when it has not been validated previously for the kind of fish under study.

Fish scales were usually mounted in a suitable medium on microscope slides and studied with the standard microscope. All measurements were made with mechanical stages and ocular micrometers. The processing of thousands of scale samples in this manner was a time-consuming and tedious process.

Early in the history of such investigations, enterprising students of the scale method strove for and developed changes in the technique of reading scales. Several models of scale projectors were developed but most of them used the microscope and prisms or camera lucida. The direct projection of scale images progressed through several stages which started with the microscope as the basic tool for magnification. Drs. John Van Oosten, Hilary J. Deason, Frank W. Jobes and Ralph Hile of the United States Fish and Wildlife Service developed a projector using microtessar lenses and standard projection equipment. This instrument went through a number of models which featured direct lineal projection onto a ground glass screen, but all of them proved to be inconvenient and cumbersome to use. Finally, a mirror was introduced into the projected beam which reflected the image onto a screen placed at such an angle that the operator could sit at the machine and read images rapidly and comfortably. Remote control attachments brought all focusing adjustments within easy reach of the operator. Refinements in design ultimately resulted in the latest model projector shown in the accompanying photograph. The ground glass screen has been replaced by a piece of rubber dental dam mounted between two sheets of glass. This surface gives a much truer image and does not reduce the quality of the image at high magnifications. The improved screen also provides a smooth glass surface upon which marks with glass-marking pencils can be made as an aid in diagnosis and then easily erased.

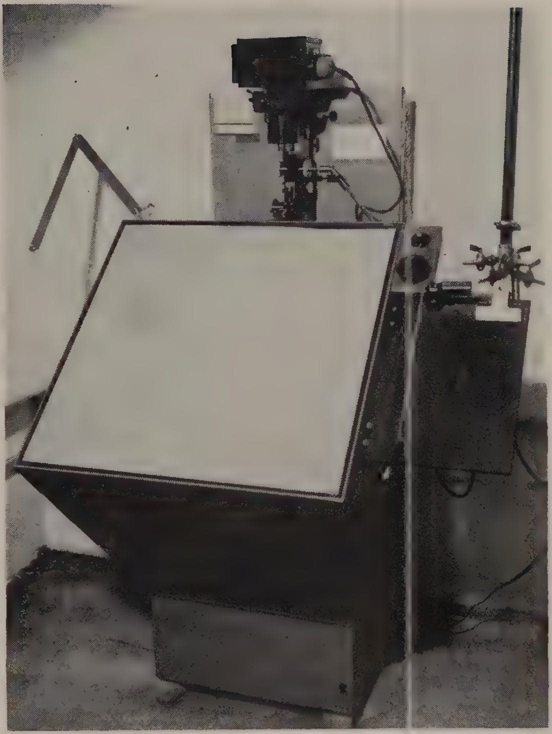
The most recent development in the scale method was made in the processing of scales for reading. Instead of mounting the scales directly on microscope slides, plastic impressions of the scale sculpturing were made. This process accelerated the preparation of specimens and also made for better interpretation especially where scales were thick enough to prevent passage of sufficient light through them to give a clear image of the sculpturing.

Several models of presses to make the impressions were evolved and the developmental phase of this work is still going on. Hydraulic jacks were adapted to press the pattern of scale sculpturing into plastic sheets of various kinds. These presses sometimes included heating plates which softened the plastic. Jeweler's presses or rollers were also used to furnish the pressure necessary to make the scale impression. No one method of making impressions is standard, as yet, since each has shown merits and disadvantages. Some methods are better adapted to making impressions of scales of certain species of fish while others give the best results with scales of different species.

Some experimentation has been done to learn the various kinds of plastic best suited to the making of scale impressions. All of the many kinds of plastic have not been tested but, currently, cellulose acetate appears to be well adapted and is widely used for this purpose.

Knowledge of the growth rate and age composition of a population of fishes is essential if the best use of that population (conservation in its true sense) is to be realized. From adequate scale studies the following points of information, among others, can be determined or partially explained: (1) the best rates of harvest, (2) the relative success of survival in various years, (3) the effects on growth of varying population densities, (4) the rate of population replacement in a given water, (5) the suitability of various fish species to a given water, (6) the average longevity of a species, and (7) the reasons for the occurence of dominant year classes in populations.

Some of the results of growth studies based on scale readings have changed materially the thinking and policies underlying the management of fishery resources. It is now widely recognized that small fish are not necessarily young fish. Many lakes and ponds full of little bluegill sunfishes and undersized black bass were protected carefully so the little fish would grow. Size limits and other legal restrictions on fishing were designed to insure that these little fellows would get bigger if left in the lake. But they didn't grow larger except very slowly. Studies of scales from these little fish proved them to be old and mature. Their chances of growing big were slight because they would die of old age before they made such growth. By chance, or accident (usually winter kill), populations in some of these lakes were reduced materially and scales from survivors of these catastrophes showed a much faster growth rate. The idea of thinning or eliminating "stunted" populations of this sort was a natural result of these observations. Now, in management of many such waters restrictions have been removed. Fishermen are encouraged to catch all they can take. No protection is afforded the fish even during spawning time and artificial stocking has been stopped. In certain stubborn cases the whole fish population is deliberately poisoned and a new stock is introduced. The new idea of keeping the fish stock down to the level of its food supply to put bigger fish in the frying pan in the shortest period of time had its birth in the scale method of age and growth determination. The condition of such fish populations can be followed constantly by means of scale analyses and the "take" can be adjusted easily to keep conditions in balance for maximum production.



Fish Scale Projection Machine.

This example is just one of many that could be cited to illustrate the value of age and growth studies from scale analyses. There is no substitute for direct knowledge of age and growth in the management of any crop of animals whether they are fish, beef cattle, or sheep. The discovery of the relationship of sculpturing and size of a fish's scales to its age and growth is probably the most significant contribution made to the present time in the field of fishery biology. ●

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MOVEMENTS OF YELLOW PERCH MARKED IN SOUTHERN GREEN BAY, LAKE MICHIGAN, IN 1950

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Abstract

To obtain information on the post-spawning movements of yellow perch that spawn in southern Green Bay, Lake Michigan, 4,172 fish caught in trap nets were marked by tagging with monel-metal strap tags attached to the right operculum and 24,799 were marked by clipping off the second or membranous dorsal fin. Marking was done during the period from May 3 to 17, 1950, at six main stations, all located in the southern end of Green Bay.

The average length of the tagged perch was 7.5 inches and all fell within the range 5.5-14.4 inches. Most (91.5 percent) of the fish were below the minimum legal length of 8.0 inches. The follow-up procedure consisted of informing commercial and sports fishermen of the program and enlisting their cooperation in watching for marked fish; accounts of the investigation were released through newspapers and descriptive posters were distributed. The personnel connected with the investigation examined catches frequently.

The large majority (101 or 79.5 percent) of the 127 tagged perch recaptured in the experimental nets during the marking operations were retaken at the tagging station at which they were released.

Of the 108 tagged perch captured by commercial fishermen and anglers following the opening of the season on May 20, 98 were taken by drop nets, 4 by gill nets, and 6 by hook and line. The mean lengths for the three groups were 8.0, 7.1, and 9.25 inches, respectively. All recoveries were made in the Wisconsin waters of Green Bay.

Most of the "open-season" recoveries (86 fish; 79.6 percent) were made during the period May 20-May 31. Recaptures during subsequent months were: June—14; July—7; August—none; September—1. Of the 86 perch recaptured May 20-31, 75 were retaken inside and 11 outside the tagging area. The majority (14 of 22) of those recovered after May 31 were retaken outside the tagging area.

The average length of the 25 tagged yellow perch recaptured by drop nets (data restricted to fish from a single type of net to avoid bias from gear selectivity) outside the tagging area (8.42 inches) was 0.96 inch greater than the mean length (7.46 inches) of the 73 fish retaken inside the area. This statistically highly significant difference lends support to the belief of commercial fishermen that the larger of the yellow perch that spawn in southern Green Bay move out soon after spawning.

The percentage of recapture of tagged perch increased sharply with increase in the size of the fish. Not one of 108 tagged fish less than 6.5 inches long was recaptured. The rates of recapture at greater lengths were: 6.5 to 8.9 inches—2.5 percent; 9.0 to 9.9 inches—11.4 percent; 10.0 to 14.4 inches—16.7 percent. Among the several factors suggested in explanation of this relationship, the most important appear to be the lesser ability of the smaller fish to survive the rigors of handling and tagging, greater loss of tags from the smaller fish, and the greater likelihood of overlooking the smaller of the tagged fish in the sorting of the catch.

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The factors just mentioned and the lack of knowledge of the efficiency of measures taken to obtain records of recoveries preclude the 2.6-percent return of all tagged fish from being accepted as an approximation of the rate of recapture. Neither should the 6.6-percent return of tagged fish of legal size (8 inches and longer) be taken as an estimate of the rate of exploitation.

Although 465 fin-clipped perch were recovered in the experimental nets during the marking operations, only 68 of 24,799 fish so marked were recovered after the fishing season opened. All but one of these 68 were retaken near the point of marking. The difficulty of detecting a perch with a missing membranous dorsal is believed to be a major cause of the poor returns from fin-clipped fish.

These investigations have demonstrated that for studying migration of yellow perch, tagging is superior to fin-clipping as a method of marking. The technique of the tagging, however, needs to be improved, and better means must be found to trace tagged fish of small size. Furthermore certain small regions in the bay not at present open to commercial fishing must be explored in order to obtain more comprehensive information as to migration.

INTRODUCTION

This report deals with a cooperative investigation made in 1950 by the Wisconsin Conservation Department and the United States Fish and Wildlife Service for the purpose of tracing the migration of yellow perch, *Perca flavescens* (Mitchill), in the Green Bay waters of Lake Michigan. Commercial fishermen of southern Green Bay long have contended that the minimum legal size for perch in that area should be less than the present 8 inches because the stock is characterized by extremely slow growth and because the larger perch leave the area soon after spawning. To obtain information on the latter point a project for the marking of spawning fish was initiated in 1948. The preliminary investigations of 1948 and 1949 produced inadequate information. The present study was more fruitful in that it yielded instructive, if not highly conclusive, data on the movements of perch and also useful information on methods for marking and procedures for a follow-up program.

The yellow perch is of primary significance in the commercial fisheries of southern Green Bay. According to statistics compiled by the Wisconsin Conservation Department the annual take of perch during the last 15 years, 1936-1950, averaged 1,199,000 pounds (range from 480,000 pounds in 1950 to 2,380,000 pounds in 1943).

MATERIALS AND METHODS

A total of 28,971 yellow perch were marked, which was nearly three times the number in either of the two preceding seasons. Full-time personnel was used for the first time in the follow-up program. All perch were captured by drop nets (a type of fyke net) which are the common gear used in southern Green Bay waters. As each net was lifted, the fish were emptied into a live car alongside the boat. The net was then reset and the boat swung free and anchored nearby. From the live car the fish were transferred to a galvanized tub, and either tagged or fin-clipped as rapidly as possible. Serially numbered monel-metal strap tags were attached to the right operculum of 4,172 yellow perch, and 24,799 perch were marked by the removal with surgical scissors of the membranous dorsal fin as close to the back of the fish as was possible without injury to the flesh.

After exploratory study of southern Green Bay, the following localities were chosen as the marking stations: off Point Comfort; off Red Banks; off the north side of Point Sauble; off the northern edge of

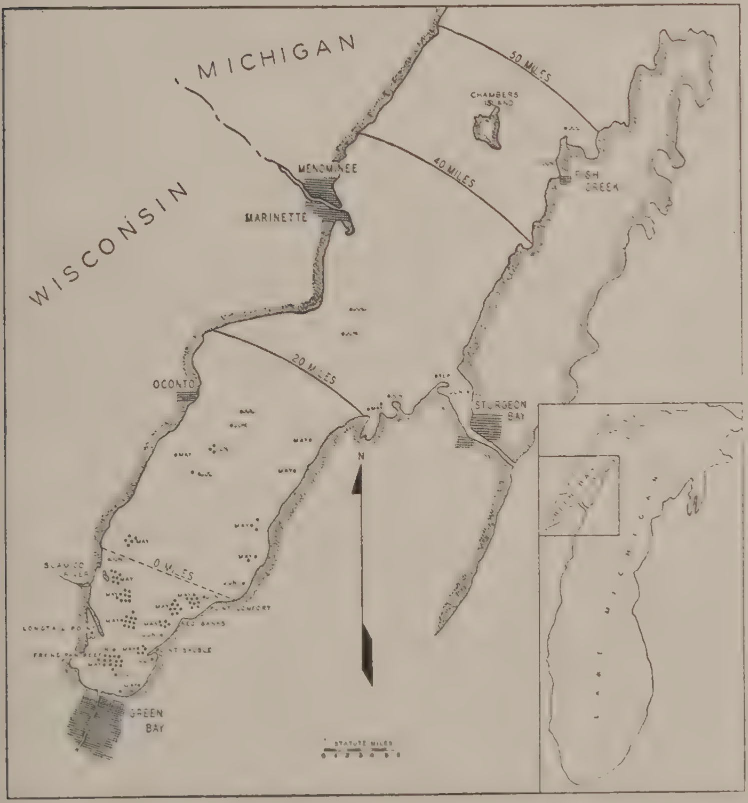
MICHIGAN
WISCONSIN
50 MILES
CHAMBERS ISLAND
40 MILES
MENOMINEE
MARINETTE
FISH CREEK
20 MILES
OCONTO
STURGEON BAY
N
0 MILES
SUAMICO RIVER
POINT COMFORT
LONGTAIL POINT
RED BANKS
POINT SAUBLE
GREEN BAY
STATUTE MILES

FIGURE 1.—Green Bay, Lake Michigan. Points and months of recovery of marked perch are indicated by dots.

Frying Pan Reef; inside Long Tail Point; and east of the Suamico River (Fig. 1). The number of yellow perch tagged and fin-clipped at these several stations, and the corresponding dates, are shown in Tables 1 and 2. The largest number, 1,093 (26.2 percent of the total) was tagged off Point Sauble, with Frying Pan Reef a close second (1,004 fish or 24.1 percent of the total number tagged). The largest numbers tagged on any one day were 973 and 970 (both 23.3 percent) on May 12 and May 13, respectively. The greatest numbers were fin-clipped at Frying Pan Reef (8,079; 32.6 percent) and at Point Sauble (5,898; 23.8 percent). The largest number of perch marked in this manner in a single day was 10,931 (44.1 percent) on May 16. The final day (May 17) was a poor second (3,211 fish; 13.0 percent).

TABLE 1.—*Number and percentage of yellow perch tagged on each date and at each locality.*[1]

Marking Locality	Number of fish tagged on date						Total	Percentage
	May 5	May 9	May 11	May 12	May 13	May 15		
Point Comfort	......	96	......	588	......	......	684	16.4
Red Banks	......	108	......	286	......	......	394	9.4
Point Sauble	......	......	709	......	......	384	1,093	26.2
Frying Pan Reef	94	......	184	......	726	......	1,004	24.1
Long Tail Point	654	......	......	......	......	......	654	15.7
East of Suamico River	......	......	......	99	244	......	343	8.2
Total	748	204	893	973	970	384	4,172	......
Percentage	17.9	4.9	21.4	23.3	23.3	9.2	......	......

[1] Fish marked from exploratory nets were assigned to the nearest principal tagging station.

TABLE 2.—*Number and percentage of yellow perch fin-clipped on each date and at each locality.*[1]

Marking locality	Number of fish fin-clipped on date									Total	Percentage
	May 3	May 8	May 9	May 11	May 12	May 13	May 15	May 16	May 17		
Point Comfort	......	564	......	364	14	739	......	1,797	......	3,478	14.0
Red Banks	......	......	......	278	230	848	......	1,681	......	3,037	12.2
Point Sauble	......	391	151	459	433	749	1,450	......	2,265	5,898	23.8
Frying Pan Reef	......	141	159	241	1,453	554	......	4,585	946	8,079	32.6
Long Tail Point	184	86	123	......	......	......	......	......	......	393	1.6
East of Suamico River	19	303	......	706	6	12	......	2,868	......	3,914	15.8
Total	203	1,485	433	2,048	2,136	2,902	1,450	10,931	3,211	24,799	......
Percentage	0.8	6.0	1.7	8.3	8.6	11.7	5.8	44.1	13.0	......	......

[1] Fish marked from exploratory nets were assigned to the nearest principal tagging station.

Because commercial fishermen were expected to make the majority of the recaptures of marked fish, a letter describing the program and requesting cooperation was sent to every Wisconsin fisherman on Green

Bay. In addition many fishermen were informed personally in both Wisconsin and Michigan and posters were placed on boat docks and at other places where fishermen were likely to see them. State and federal biologists accompanied commercial fishermen as often as possible to inspect the catches. Wisconsin and Michigan conservation officials cooperated by inspecting catches at fishing establishments and aboard boats. Valuable aid was also given by newspapers that published accounts of the project.

RECAPTURE OF TAGGED FISH DURING THE MARKING PERIOD

Of the total of 127 tagged yellow perch recovered from the nets during the marking operations, 101 (79.5 percent) were retaken at the same locality and 26 (20.5 percent) were retaken at other marking stations. Nearly all of the fish recaptured at the same locality were caught soon after tagging, usually the next time the net was lifted.

TABLE 3.—*Number and percentage of tagged yellow perch recovered at various distances from tagging area within different periods of time.*

Distance from point of tagging[1] (miles)	Period of recovery						Total recovered	Percentage recovered
	May 20–31	June 1–15	June 16–30	July 1–31	Aug. 1–31	Sept. 1–30		
Nil[2]	70	5	....	3	....	....	78	72.2
<20	15	4	....	2	....	....	21	19.4
20 to 40	1	3	1	1	....	1	7	6.5
40 to 50	....	....	1	1	....	....	2	1.9
Total	86	12	2	7	....	1	108	....
Percentage	79.6	11.1	1.9	6.4	....	0.9	....	....

[1] Computed from northern limit of tagging area as shown in Figure 1.
[2] Recovered in tagging area.

The longest interval for recovery during the marking period for any tagged fish was 11 out of a possible 12 days. All of the 127 recaptured tagged fish that were alive were returned to the water and none was again retaken during the marking operations. However, 3 were recaptured later in the year.

The condition of the gills and operculum of the recaptured tagged fish varied from an excellent to a badly irritated state. Several of the tags were found to be loosened.

RECAPTURE OF TAGGED PERCH AFTER THE MARKING PERIOD

The commercial fishing season for yellow perch opened in Wisconsin on May 20. Nets were set on this date, and the first lifts were made by most of the fishermen on May 22. The last 12 days of May yielded the largest number of returns (86 tagged fish or 79.6 percent of the total were recaptured during this period, Table 3). Twenty-one fish were recaptured during June and July, but there were no returns during August. On September 12, a fish that had been tagged at Point Sauble on May 15 was taken in a gill net near Sherwood Point Light at the entrance to Sturgeon Bay. This was the last tagged perch recaptured.

Of the 108 tagged fish recovered, 96 were taken by drop nets, 6 by gill nets, and 6 by hook and line. Three of these last 6 represented the most distant returns.

We have only one record of the recapture of a tagged fish more than once during the fishing season. An 8.0-inch yellow perch tagged at Point Sauble (east shore) on May 12 was recaptured at Little Tail Point (west shore) on May 23 by a commercial fisherman, and released. It was captured again at Red Banks (east shore) on May 31 by another commercial fisherman.

Recoveries from different tagging stations and dates.—With the exception of Long Tail Point for which the percentage return was only 0.8 percent (Table 4), the percentages of recapture of fish tagged at different localities varied little (range from 2.5 percent at Point Comfort to 3.2 percent east of the Suamico River). The percentages of recovery according to date of tagging (Table 5) exhibited a considerably greater range (from 1.1 on May 5 to 6.5 on May 15) and also showed a tendency toward a definite if irregular increase from the earliest to the last date. This increase may be associated with the length of time during which the fish were subject to post-tagging mortality before they had a chance to be recaptured after the opening of the season on May 20.

TABLE 4.—*Number and percentage of yellow perch returned from each tagging locality.*

Tagging locality	Number tagged	Number returned	Percentage returned
Point Comfort	684	17	2.5
Red Banks	394	12	3.1
Point Sauble	1,093	33	3.0
Frying Pan Reef	1,004	30	3.0
Long Tail Point	654	5	0.8
East of Suamico River	343	11	3.2
Total or average	4,172	108	2.6

Time out and distance traveled.—The records of distances from the tagging area, with corresponding dates, for the 108 recaptured yellow perch (Table 3 and Fig. 1) reveal that the great majority of the fish —72.2 percent of all those caught—were recaptured within the tagging area; 19.4 percent were recaptured in localities less than 20 miles distant; 6.5 percent at 20 to 40 miles; and 1.9 percent at locations 40 to

50 miles distant from the tagging areas. The tagged perch retaken at the greatest distance from the point of release was caught by hook and line on July 30 off Peninsula State Park, near Ephraim, Wisconsin. This fish had been tagged on May 15 at Point Sauble. On the same day, however, another fish that had also been tagged on May 15 at Point Sauble was caught by hook and line only a few hundred yards from the Point. These figures indicate a great variation in movement of individual perch.

The recovery of the tagged yellow perch at different localities depends not only on the migration of these fish but also on the existence of the means to capture them. A decisive role is played by the extent of fishing operations and by the type of gear used in different areas and during different periods. The total number of recoveries in the present experiment was too small to warrant an analysis of the recaptures according to locality and date in relation to fishing pressure. It can be stated, nevertheless, that the facilities for recovery were generally good, since the Wisconsin waters of Green Bay comprise one of the most heavily exploited (by both sport and commercial fishermen) areas of the Great Lakes and Michigan waters of the bay are also heavily fished. The greatest weakness existed in Door County, on the eastern upper half of the Wisconsin waters where regulations prohibit the use of the drop net, a gear particularly effective for taking perch. The principal type of gear in these waters is a 2½-inch-mesh gill net that ordinarily catches few or none of the smaller fish. This problem of gear selectivity and the matter of overlooking tagged fish in certain fisheries will be treated in a later section.

TABLE 5.—*Number and percentage of tagged yellow perch returned from each tagging date.*

Tagging date	Number tagged	Number returned	Percentage returned
May 5	748	8	1.1
May 9	204	4	2.0
May 11	893	16	1.8
May 12	973	28	2.9
May 13	970	27	2.8
May 15	384	25	6.5
Total or average	4,172	108	2.6

Despite the relatively small total number of recoveries, there appears to be a definite relationship between time elapsed after tagging and the distance moved before recapture. Of the 78 fish retaken within the tagging area, 70 (90 percent) were caught during the period May 20-May 31 and 8 (10 percent) on later dates; of 21 perch taken outside but not more than 20 miles from the region of marking 15 (71 percent) were captured during May 20-May 31 and 6 (29 percent) later; of

9 fish recaptured 20 to 50 miles from the tagging area only 1 (11 percent) was caught during May 21-May 31 and 8 (89 percent) were taken on later dates. The application of the Chi-square test demonstrated that the proportions of fish captured May 20-31 and after May 31 differed significantly among all three recovery zones listed in Table 6.

TABLE 6.—*Comparison of numbers of tagged yellow perch recaptured May 20-31 and after May 31 within the tagging area and at various distances from it.*

[Data condensed from Table 3]

Distance from point of tagging[1] (miles)	Period of recovery	
	May 20-31	June-September
Nil[2]	70	8
<20	15	6
20 to 50	1	8

[1] Computed from northern limit of tagging area as shown in Fig. 1.
[2] Recovered in tagging area.

Average length and locality of recapture.—To avoid possible bias from the selective action of the gear, the data of Table 7 on the relationship between the length of recaptured tagged perch and locality of recovery were based exclusively on fish taken in drop nets, which accounted for 96 of the 108 recaptures. In two of three comparisons the mean lengths of yellow perch retaken outside the tagging area were greater than the lengths of fish recovered in the area by a highly significant margin. The June-July recoveries yielded indefinite results, probably because small numbers of fish (6 in the tagging area and 9 outside) were taken. The combined May-July samples indicate an average difference of nearly an inch between the lengths of the 76 perch

TABLE 7.—*Comparison of the average lengths of tagged yellow perch recovered by means of drop nets inside and outside the tagging area over different periods of time.*

Date of recapture	Area of recapture				Difference between means	Value of p[1]
	In tagging area		Outside tagging area			
	Number of fish	Average lengths (inches)	Number of fish	Average lengths (inches)		
May 20-31	70	7.47	11	8.77	1.30	<0.01
June 1-July 31	6	7.32	9	7.99	0.67	>0.05
May 20-July 31[2]	76	7.46	20	8.42	0.96	<0.01

[1] Determined from the Behrens-Fisher test; Student-Fisher test not applicable by reason of unequal variance. See p. 111 *et seq.*, Vol. 2 of: Kendall, Maurice, "The advanced theory of statistics," 2nd Ed., Charles Griffin and Co., Ltd., London, 1948.

[2] The May and the June-July samples of fish taken in the same area exhibited no significant differences of the mean or of the variance.

recovered within the area of tagging (mean of 7.46 inches) and of the 20 fish taken in more northerly waters (mean of 8.42 inches). Scanty as these data are, they lend strong support to the belief of commercial fishermen that the larger of the yellow perch that spawn in southern Green Bay tend to desert the area after spawning.

RELATIONSHIP BETWEEN LENGTH OF FISH AND PERCENTAGE OF RECAPTURE

The data on the length-frequency distributions of yellow perch tagged and fish recaptured and on the percentage of recapture at different lengths (Table 8) demonstrate that the program was far more successful for the large than for the small fish. The recaptured fish averaged longer (7.7 inches) than the perch tagged (7.3 inches), the frequency distributions of the two groups were dissimilar (that the difference between the distributions was significant was proven by the Chi-square test), and the percentage of recapture exhibited a strong if irregular tendency to increase with increase in the length of the fish.

TABLE 8.—*Comparison of length-frequency distribution of yellow perch tagged and of tagged fish recaptured.*

Total length (inches)	Fish tagged		Fish recaptured		Percentage of recapture
	Number	Percentage	Number	Percentage	
5.5— 5.9	2	[1]0.0	....	....	0.0
6.0— 6.4	167	4.0	....	....	0.0
6.5— 6.9	934	22.4	13	12.0	1.4
7.0— 7.4	1,753	42.0	41	38.0	2.3
7.5— 7.9	937	22.5	29	26.8	3.1
8.0— 8.4	232	5.6	12	11.1	5.2
8.5— 8.9	67	1.6	2	1.9	3.0
9.0— 9.4	32	0.8	4	3.7	12.5
9.5— 9.9	12	0.3	1	0.9	8.3
10.0—10.4	11	0.3	2	1.9	18.2
10.5—10.9	6	0.1	2	1.9	33.3
11.0—11.4	6	0.1	1	0.9	16.7
11.5—11.9	5	0.1	....	....	0.0
12.0—12.4	4	0.1	1	0.9	25.0
12.5—12.9	3	0.1	....	....	0.0
13.0—13.4	....	....	....	....	....
13.5—13.9	....	....	....	....	....
14.0—14.4	1	[1]0.0	....	....	0.0
Total	4,172	....	108	....	2.6
Average length	7.3	....	7.7	....	....

[1] Less than 0.05.

How greatly the percentage of recovery varied with the size of the fish is brought out by the summary of the data for the selected intervals of length shown in Table 9. Not one of the 169 tagged yellow perch within the length range 5.5-6.4 inches was retaken. The percentage was small (2.5 percent) at 6.5-8.9 inches although so many of the tagged fish fell within this range that the actual number of recaptures

(97) was large. At 9.0-9.9 inches the percentage of recapture jumped to 11.4—more than 4 times the value at 6.5-8.9 inches—and at 10.0-14.4 inches it was even greater (16.7 percent).

Clear-cut as the evidence is that the percentage of recapture improved with increase in the size of the fish, there is no good information available to explain the relationship. The following factors are suggested as the more important: greater loss of tags from small than from large fish; greater ability of large than of small fish to survive the rigors of handling and of carrying tags; greater probability of recapture of the larger fish by means of the fishing methods employed; greater chance of detection of the larger tagged fish in the sorting of the commercial catch; differences in the pattern of movement that carried a large percentage of the smaller fish into areas where they were not subject to capture. Of the several "explanations" listed above only the last can be held strictly speculative. Evidence strongly favors the view that the other factors actually did contribute to the relatively higher rate of recapture of the larger yellow perch.

TABLE 9.—*Percentage recovery of tagged yellow perch at certain selected intervals of length.*

[Data condensed from Table 8]

Length interval (inches)	Number tagged	Number recaptured	Percentage of recapture
5.5— 6.4	169	0	0.0
6.5— 8.9	3,923	97	2.5
9.0— 9.9	44	5	11.4
10.0—14.4	36	6	16.7

The tags themselves were poorly suited for marking small fish. Each arm of the tags measured about one-half inch and the average weight was a little greater than 0.5 gram (a sample of 25 weighed 13.0 grams). Tags of this size must place small fish under a severe handicap and certainly they would be more likely to wear their way through the operculum and become lost from small than from large individuals.

The possible effects of the selective action of the gears of recapture are difficult to assess. Commercial drop nets, the type of gear employed to take fish for tagging (and the gear from which 96 of the 108 recoveries were obtained) would not be expected to be selective in recapturing the same fish. Commercial gill nets which accounted for 6 recaptures ordinarily take few perch less than 8 inches long. The tagged fish captured by this gear, however, were small — averaging only 7.1 inches as compared with 7.7 inches for perch recovered in drop nets. It is probable that selective action normally exerted by gill nets in the taking of yellow perch does not apply to tagged fish since some of the small tagged perch had been caught by the tangling of the tag in the webbing of the gill nets. The six yellow perch retaken by hook and line averaged 9.25 inches. Three of the six were more than 9 inches long (largest, 12.1 inches) and none were below 7.3 inches.

The method of sorting employed by drop-net fishermen of southern Green Bay tends to cause tagged fish of less than legal length (8.0 inches) to be overlooked. In the standard procedure the net is emptied on the deck of the boat and the fish are picked up with scoop-shovels. The legal-sized fish are removed from each shovelful and the remainder tossed overboard. Since this sorting is carried out rapidly as a protection to the undersized fish which strongly predominate in the drop-net catches, smaller individuals are not carefully observed. The strap tags were not highly visible and if a fish happened to be lying on its right side there was no opportunity for detection of the mark. Failure to see the mark on undersized fish could not explain the changes in the percentage of recapture among the lengths greater than 8.0 inches. In the Michigan waters of Green Bay the chances of overlooking tags on the smaller fish were even greater since the larger size limit (8½ inches as compared with 8 inches in Wisconsin) leads to mass rejections of undersized fish.

The factors outlined above together with our general uncertainty about the actual effectiveness of the program to obtain reports of all recoveries that were noticed make it impossible to accept the 2.6-percent return of yellow perch of all sizes as even an approximate measure of the rate of recapture. Likewise the 6.6-percent recovery of legal-sized fish is not believed to be a sound estimate of the rate of exploitation.

The restriction of tagging to the larger fish would increase the efficiency of recovery, but it is as important for an understanding of movements of the spawning population to have data on the small perch as on large ones. Furthermore, relatively few large fish were available for tagging.

RECAPTURE OF FIN-CLIPPED FISH

The open-season recovery of fin-clipped yellow perch was small. During marking operations, 465 fish were retaken in the nets. As in nearly all of these perch the wound seemed to have healed rapidly with little or no infection, high hopes were held for a successful return during the summer. However, after the commercial season opened, only 68 of the 24,799 fin-clipped fish were recaptured (Table 10). Of these 68 recaptures, 64 occurred during May, and 67 were found close to the point of marking. Only one fin-clipped fish was taken at a considerable distance from the point of marking. It was recaptured on June 28 near Peshtigo Reef on the west shore approximately midway between Marinette and Oconto (Figure 1). Only 3 other recaptures were reported in the month of June. The men checking catches reported that perch usually depressed their dorsal fin when removed from the water; therefore very close scrutiny was necessary to determine whether this fin had been removed. Because the time required to make close examination was prohibitive, it is possible that many fin-clipped fish escaped recognition. It is also to be noted that some fin-clipped perch kept for observation in a pond at Sturgeon Bay showed slight to moderate fin regeneration. This fact suggests further difficulty in the quick recognition of this type of marking.

TABLE 10.—*Location, date, and number of fin-clipped fish recovered.*

Location	Date	Number recovered
Geanos Beach	May 23	3
Frying Pan Reef	May 23	4
Point Sauble	May 23	3
Vincent Point	May 24	5
North of Dykesville	May 24	3
Red Banks	May 24	2
Point Sauble	May 24	2
North of Little Tail Point	May 25	15
Geanos Beach	May 25	8
Red Banks	May 25	8
Point Comfort and Frying Pan	May 25	7
East of Suamico River	May 26	3
Frying Pan Reef	May 27	1
Point Sauble	June 2	1
Point Sauble	June 5	1
Whitney Bluff	June 9	1
Peshtigo Reef	June 28	1
Total		68

The results from the fin-clipping lead to the conclusion that the advantage offered by this technique over tagging in terms of the large numbers of fish that can be handled is outweighed by the difficulty of recognizing fin-clipped specimens and the loss of records for individual fish.

ACKNOWLEDGMENTS

The tagging party consisted of: Joseph DeWitt and Joseph DeWitt, Jr., commercial fishermen from Suamico, Wisconsin; Ralph Hile, Leo F. Erkkila, and Donald Mraz of the U. S. Fish and Wildlife Service; and Robert Balch of the Wisconsin Conservation Department. Matt Patterson, Donald Euers, and the warden staff of the Wisconsin Conservation Department assisted in the preliminary arrangements and follow-ups. Leonard Joeris of the U. S. Fish and Wildlife Service was present for the follow-up. Hundreds of commercial and sports fishermen aided the program by checking their catches and reporting tagged and fin-clipped fish.

Dr. Ralph Hile, of the Fish and Wildlife Service, read my original manuscript, and Mr. Walter Haertel helped prepare the chart (Fig. 1) showing the locations of tag recoveries. Statistical tests employed in the analysis of certain data were made by George F. Lunger of the Service.

NEW TUNA SOURCE

Fish and Wildlife Service's Investigation Reveals Potential New Grounds

by
GARTH MURPHY
and
RICHARD S. SHOMURA

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Portion of a typical catch of longline tuna on board the vessel *Hugh M. Smith*. —(Photograph by Dixon Stroup)

A POTENTIAL new source of tuna has been located in the Central Pacific by the U. S. Fish and Wildlife Service's Pacific Oceanic Fishery Investigations, directed by O. E. Sette. These rich new tuna grounds are in a zone running east and west, parallel to the equator and somewhat north of it. Actual catches so far have been best between 1° and 6°N., but propably the zone shifts north and south with the ocean currents. In an eastward direction fishing has been done between 150° and 165°W. It remains to be found out how much farther to the east and to the west the tuna concentration extends.

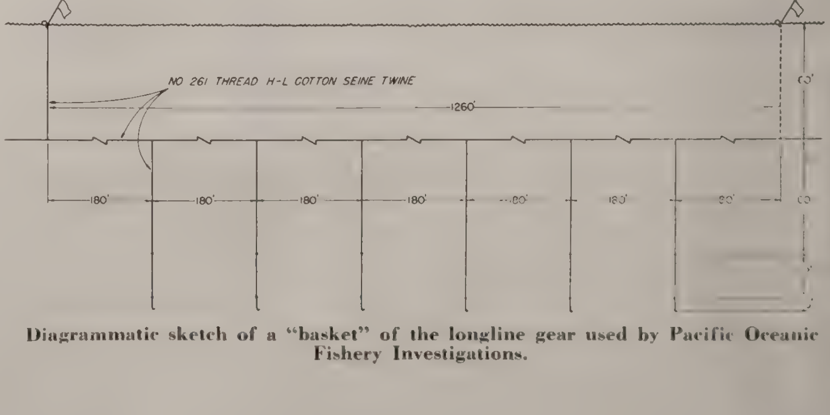
Surface schools of small and medium-sized fish familiar to West Coast live-bait and purse seine fishermen are scarce in the zone, except in very small areas immediately around the small islands such as Christmas, Fanning, and Palmyra. Away from such islands surface signs of fish are almost nonexistent. But regardless of islands, the medium and large tuna that swim at depths of 100 to 400 feet are plentiful everywhere within the zone. These deep-swimming tuna cannot be caught by conventional live-bait fishing and purse seining, but were readily taken by longline gear, called "flaglines" in Hawaii.

That there might be such a zone of tuna concentration was first suspected because hydrographic data showed a band of "upwelling" along the equator. "Upwelling" is a term used by oceanographers to describe the rising of water from the depths of the ocean to the surface. The deeper water is rich in nutrients and when it gets close enough to the surface to be reached by sunlight, minute plants thrive in it. Microscopic animals feed on these tiny plants, and they in turn become food for fish. Because of this, the abundance of all fishes depends on the amount of nutrients in the water, just as the yield of a crop on land is controlled by the fertility of the soil. Upwelling, incidentally, is largely responsible for the rich fish resources along the California coast.

Oceanographic evidence shows that rich water rises toward the surface at the equator, flows north, and then sinks down again. The location of this sinking is variable and it is sometimes strong and sometimes weak. Although the causes of the upwelling and sinking have not yet been fully explained, it is connected with the southeast trade-winds and it unquestionably is going on most of the time. The minute animals of the ocean called "plankton" were quite clearly multiplying very vigorously in the equatorial zone of upwelled water with its store of nutrients, for tow nets hauled in the zone caught several times more plankton there than in the waters immediately to the north and south. Having learned this much, the next question was whether or not tuna would be as strikingly abundant in this rich zone. We had already found surface fish to be abundant close to the islands in this area, but not more than a few miles away from land.

To answer this question, the research vessel *Hugh M. Smith* made a longlining cruise in October and November of 1950. During this cruise, 27 locations were fished between 157° and 168°W., crossing the equator once at 158°W. Tuna were captured at the rate of 3.00 per hundred hooks per day of fishing north of the rich zone and 9.26 per hundred hooks within the rich zone. Despite the fact that this first cruise was a trial of several kinds of longline gear, some of which did not operate satisfactorily, the results were very encouraging. Most important, it proved that knowledge of the current system and its effects on plankton could lead to finding fish concentrations in the equatorial Pacific.

During August and September of 1951, the *Hugh M. Smith* made a combination hydrographic and longline fishing cruise along the meridian of 150°W., and along the parallel of 2°N.



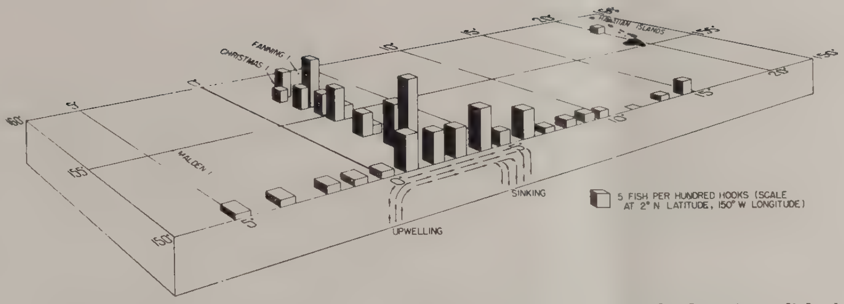
Diagrammatic sketch of a "basket" of the longline gear used by Pacific Oceanic Fishery Investigations.

between 150° and 158°W. This cruise was designed to record the hydrographic conditions and the abundance of fish simultaneously. The locations fished and the results obtained are shown on the accompanying figure.

At the 12 stations to the north and south of the rich area 31 yellowfin tuna, 44 big-eyed tuna, 4 skipjack, and 4 albacore were caught for an average catch of 2.86 tuna per hundred hooks. At the 16 stations, within the rich area 427 yellowfin, 50 big-eyed tuna, 19 skipjack, and 3 albocore were caught for an average of 12.9 tuna per hundred hooks. The most spectacular catch consisted of 72 tuna, 71 of which were yellowfin. The yellowfin taken on this cruise ranged from 30 to 190 pounds, with an average weight of 124 pounds. The big-eyed tuna were somewhat larger, and the skipjack and albacore were, of course, a good deal smaller. In summary, fishing in the rich band yielded an average of 12.9 tuna per hundred hooks, weighing a total of 1,600 pounds. Outside of the rich zone, the catch per hundred hooks was 2.86 tuna, weighing 360 pounds.

The longline gear used on this cruise was developed by the staff of the Pacific Oceanic Fishery Investigations as a modification of the gear used by Hawaiian and Japanese fishermen. The entire set is divided into units called "baskets." Each basket has 6 hooks, which are baited with frozen sardines toughened by soaking in heavy brine. The mainline of each basket is set slack, so that it sags down 300-400 feet halfway between buoys, with hooks fishing at various depths from 130 to about 500 feet. The *Hugh M. Smith* fished 40 baskets of gear, or 240 hooks, at each station, the lines being set at dawn, and the first basket being retrieved shortly after noon. The last basket was brought aboard around five in the afternoon, after which the *Smith* proceeded to her next station. A Japanese line-hauler was used to retrieve the lines. The handling of this gear, though simple in principle, requires great dexterity and exact timing on the part of the fishermen.

There are some comparative data available with which to evaluate the richness of this area and the performance of the longline gear. In the far western Pacific a number of post-war Japanese mothership expeditions have averaged about 3.13 tuna totaling 250 pounds per hundred hooks. A typical Japanese longliner might weigh 150 tons and carry 25 fishermen. This vessel would fish about 2,000 hooks, and at the above rate would average about 5,000 pounds of tuna per day. This is a low return per man and this return is acceptable only because Japanese fishermen receive low pay and are willing to work excessively long hours.



Diagrammatic representation of the Central Pacific showing the locations fished during the fall of 1951 and the relative sizes of the catches. Note that the heavy catches coincide with the presence of upwelled water.

The question of whether these richer grounds south of Hawaii could support American living standards has to be answered in terms of how much gear could be operated and how much it would catch.

The *Smith* is a clippertype vessel and very awkward to handle when hauling in longline. Our West Coast purse seiner type would be much handier and we think such a vessel with an American crew of 12 men could fish at least 600 hooks a day. Fishing in the rich latitudes in the neighborhood of 150°W this would bring in 9,600 pounds of tuna per day, providing the tuna were present in the abundance experienced during the last cruise of the *Smith*. This is about 4 times more per man than the typical Japanese catch.

The estimated catch of the American boat is based on what is actually relatively crude, unimproved gear, and it would be surprising if ingenious fishermen could not raise its efficiency. It is likely also that further biological study of the tuna will also help improve the catch, especially in regard to such problems as the best depths for fishing in various parts of the current system. A feature in favor of the longline is the relative steadiness of the catch. There are variations in the catch rates of different vessels, as there are in all fisheries, but some problems, such as procurement of bait and location of surface schools, are absent, so that once a productive ground is located, it can be worked with a reasonable assurance of catching fish. Even much of the trial and error in finding productive grounds is eliminated through the knowledge of the oceanographic and biological conditions that make for richness.

Aside from questions of the efficiency of the longline gear and its productivity in economic terms, there are a number of important things to look into. Prominent among these are the following: What is the seasonal variation in abundance of the tuna in the "rich zone?" And, what are the eastern and western limits of equatorial concentration of tuna? The two cruises on which this article is based took place in the late summer and fall. While there is good reason to believe that seasonal fluctuations in the abundance of longline tuna in the equatorial regions are slight, only fishing throughout the other months of the year can prove it. Similarly, no exploratory fishing has been done east of 150°W., but there is an indication in data on the Southeast Trades that suggest yellowfin tuna should be more abundant to the east of 150°W.

Work is planned by the Pacific Oceanic Fishery Investigations toward getting answers to these questions. During the first half of 1952 the *Hugh M. Smith* and the *John R. Manning* will continue to do hydrographic work and fishing along the equatorial zone between 130° and 180°W. longitude. In this manner, the powerful tool formed by integration of fishing, oceanography, and biology will continue gathering information for the ultimate expansion of the high seas tuna fishery.

The *Hugh M. Smith*, one of the Fish and Wildlife Service's research vessels stationed at Honolulu. —(Photograph by M. B. Schaefer)

HUGH M SMITH

THE EFFECTS OF
SUPPLEMENTAL FATS IN THE DIET OF BROOK TROUT

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FATS IN THE ANIMAL BODY serve as a source of immediate energy, as a reserve source of energy, as insulation against climatic changes, as a protection for the vital organs, and as a lubricant for many of the moving parts. Fats also serve as carriers for the so-called fat-soluble vitamins (D, E, K, and A). Fat in the body is derived from the food that is eaten: fat may be deposited from the fats in the diet or may be formed from excessive carbohydrates and proteins. That fats are essential in the diet has been demonstrated with the higher animals. It has been found that at least one of the fatty acids (the building blocks of fats) is needed to maintain a normal healthy animal.

Two types of fat are found in the animal body: the constant and the variable. The constant fat is that which is present in the body cells even after long periods of starvation and apparently represents the minimum amount of fat necessary to maintain life. The variable fat, as the name indicates, fluctuates widely from animal to animal and may vary considerably in the same animal over periods of time. The variable fat is dependent upon the food eaten, and overeating of any or all of the food groups (protein, fat, or carbohydrate) may result in an excessively fat animal. It is well known that animals that are greatly overweight are not desirable over a long range, but little work has been done to determine the effect of fat on the physiology of the trout. The Cortland workers recently have started such experiments in the hope that some information may be gained as to the utilization of these substances and their effects upon the fish.

Several authors have reported that cod-liver oil in the diet of trout resulted in an increased rate of growth of the fish (Davis 1927; Gutsell 1939, 1948; Phillips et al. 1948, 1949, 1950). These papers did not indicate whether the increased rate of growth was due to the vitamin content (A and D) of the oil, a combination of the vitamins, the energy of the oil itself, or to some other unknown factor.

McLaren and associates (1947) concluded that the addition of corn oil to the diet of rainbow trout produced beneficial effects, not from the angle of growth, but as measured by the fat content of the body and the reduced mortality of the fish.

McCay and Tunison (1935) fed cottonseed oil (a commercial oil suitable for human consumption) for 32 weeks and reported that it was evident that the oil was utilized. This diet, together with one containing crisco (hydrogenated cottonseed oil), showed an increased rate of growth in comparison to the control diets. Later these authors (1936) conducted balance trials, using salmon and cottonseed oil as well as crisco. They found that the oils were equally digested (about 90 percent) even though one was of fish and the other of vegetable origin, whereas only about 70 percent of the crisco (a harder fat than the two oils, solid at room temperature) was digested.

PROCEDURE

During the summer of 1950, experiments were run at the Cortland Hatchery to study the effect of several oils upon the growth rate, mortality, and chemical composition of the body. Two vegetable fats (corn and cottonseed oil) and two fish fats (cod-liver and salmon oil) were added to the standard diet of this hatchery at two levels (3 and 5 percent of the diet). The fish were held in troughs supplied with water at a temperature of 47° F. and the experiments were run

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for 22 weeks. The fish were handled according to the established procedure of this laboratory (Tunison et al. 1939).

At the end of 16 weeks, groups of fish were removed from each of the experimental troughs, killed, dried under vacuum, and then ground in a mortar. Analyses were then made for the fat, ash, and protein content of the various dried and ground trout. Also, the character of the fat was established by determining the iodine number of the fat extracts.[1]

The original intention was to take samples of fish for analysis at the end of the experimental period (22 weeks), but only one series was made.

All differences were tested statistically by means of analysis of variance. The diet composition is listed in table 1, and the results are summarized in table 2.

EXPERIMENTAL RESULTS

The addition of corn oil did not increase the rate of growth at either level in comparison to the control diets and did not alter the mortality rate of the fish. The total percent of fat in the body was increased beyond that of the control, although the higher level of oil did not produce a greater storage of fat than the lower.

Whether the increase in body fat was beneficial or not, certainly appears debatable. In terms of actual trout production, the deposition of fat could hardly be classified as true growth, as it was not fish flesh or protein that was deposited. The growth rate of trout fed corn oil was similar to that of trout receiving the control diet, but the bodies of the oil-fed trout showed considerably higher fat content. It would appear logical to conclude that even though the two groups showed similar average weights at the end of the experimental period, the fish fed corn oil, showing the higher fat content and hence a smaller amount of trout flesh per animal, actually gained less than the control lot.

The effect of corn oil on the body fat of the fish was reflected by the increased iodine number of the body fat. As, in general, the iodine number of a fat is a measure of hardness (melting point), the higher iodine number of the fat indicates a softer body fat, providing additional proof of the utilization of the dietary oil.

TABLE 1.--Percentage composition of the diets

Diet No.	Beef spleen	Dry mix 6a[1]	Corn oil	Cotton-seed oil	Cod-liver oil	Salmon oil
1193	50	50	-	-	-	-
1194	50	50	-	-	-	-
1195	47	50	3	-	-	-
1196	47	50	3	-	-	-
1197	45	50	5	-	-	-
1198	45	50	5	-	-	-
1199	47	50	-	3	-	-
1200	47	50	-	3	-	-
1201	45	50	-	5	-	-
1202	45	50	-	5	-	-
1203	47	50	-	-	3	-
1204	47	50	-	-	3	-
1205	45	50	-	-	5	-
1206	45	50	-	-	5	-
1207	47	50	-	-	-	3
1208	47	50	-	-	-	3
1209	45	50	-	-	-	5
1210	45	50	-	-	-	5

[1] Composed of 24 parts each of wheat middlings and cottonseed meal, 48 parts fish meal, and 4 parts salt.

The addition of cottonseed oil at either level resulted in almost no growth over the 22-week period. The iodine number of the body fat indicated that the fish were utilizing the oil, but the total fat content of trout fed this oil was lower than the fat content of the fish fed the regular diet. The low growth rate was further evidenced by the reduced protein content of the body. The feeding of this oil caused an increased mortality, and the surviving trout were in extremely poor physical condition.

This study is in agreement with the work of McCay and Tunison (1935) in that the iodine number of the body fat clearly indicates the absorption of the oil into the body. The earlier study, however, did not show a similar lack of growth and increased mortality, possibly because the grade of oil used was better.

There appears to be a wide variation in the amount of gossypol in various cottonseed oils (Eagle et al. 1948; Iwai and Nakamura 1944; Williams et al. 1949), and this may best explain the difference between the present experiments and those of McCay and Tunison (1935).

As in earlier work, the addition of cod-liver oil at a 3-percent level resulted in growth rates that far exceeded those of the control diets. Increasing the amount of the dietary oil to 5 percent reduced the growth rate below that of the control fish. These experiments, therefore, established the limit of cod-liver oil at about 3 percent of the diet for optimum growth. Both levels of the oil increased the total body fat, and an increase in the iodine number was found. There was no percentage increase in the protein content of the body; but, because there was an increase in fish size, the number of grams of protein per individual was greater in the fish fed cod-liver oil (3-percent level).

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[1] Methods for analyses: fat, ether extract; ash, to constant weight in a furnace; iodine number, Hanus; protein, micro-nitrogen, Hengar.

In this case it is felt that there was a gain in fish flesh, in spite of the increased fat deposition. This is due to the stepped-up growth, and it is believed that the addition of the fat definitely was beneficial. These results are in decided contrast with those from corn oil, which produced increased fat at the same growth rate as the controls.

Salmon oil produced results similar to those noted for cod-liver oil. At the 3-percent level there was a marked increase in the rate of growth, the total body fat was greater in comparison with the controls, and the iodine number of the body fat was increased. The 5-percent level did not show the marked decrease in growth rate that appeared when the same level of cod-liver oil was fed. During the last three 2-week periods of the experiment, however, the fish fed the greater amount of salmon oil were showing a decreased rate of growth as compared with that of the fish given the lesser amount of oil. It is believed that if the experiment could have been continued for a longer period, a definite and significant reduction in growth rate would have been observed.

In several instances the trout fed both the cod-liver and the salmon oil showed a significant increase in mortality over short periods. This may possibly be traced to the stepped-up rate of growth resulting from the oil. Phillips and his associates (1949) pointed out that trout fed diets containing cod-liver oil showed a higher loss when these diets were not additionally fortified with either beef liver or dried brewers' yeast, possibly because of an increased requirement for the vitamin biotin.

DISCUSSION

In regard to growth rate, neither corn oil nor cottonseed oil had any beneficial effect when added to the diet of trout; in fact, cottonseed oil was detrimental. The feeding of either cod-liver oil or salmon oil at a 3-percent level was beneficial; the 5-percent levels were either detrimental or less effective than the lower amounts.

The cod-liver oil and salmon oil are good sources of vitamins A and D. It is probable that some combination of the vitamins or some other unknown substances are responsible for the increased rate of growth resulting from

TABLE 2.--Effect of dietary fat upon the chemical composition of brook trout

Diet number	Added fat	Percent fat	Iodine number	Percent protein[1]	Percent ash	Average weight end[2]	Percent average 2-week mortality	Total percent gain	Percent water
1193	none	3.75	92.2	14.1	2.0	10.78	2.2	1,180	78.5
1194	none	3.10	92.6	13.7	1.7	9.45	2.2	1,025	80.3
1195	(3/)	5.55	106.9	14.8	2.2	10.00	2.7	1,090	75.6
1196	(3/)	5.30	103.3	14.3	1.9	9.40	2.2	1,019	78.0
1197	(3/)	5.05	107.9	13.7	2.0	9.46	2.5	1,026	78.6
1198	(3/)	4.90	108.3	13.9	2.0	9.20	3.2	999	78.5
1199	(4/)	2.65	111.0	13.5	2.3	1.73	4.9	106	80.6
1200	(4/)	2.75	108.3	12.5	2.4	1.54	4.7	85	82.0
1201	(4/)	1.55	121.2	11.3	2.1	.90	7.6	7	84.5
1202	(4/)	2.00	117.9	10.4	2.0	1.30	9.9	55	84.6
1203	(5/)	4.80	105.6	15.2	1.8	17.30	4.3	1,620	77.6
1204	(5/)	4.70	103.5	13.6	1.9	14.24	3.1	1,595	79.0
1205	(5/)	5.60	109.6	15.0	1.9	8.75	3.1	944	77.0
1206	(5/)	4.70	107.4	11.3	1.6	7.39	2.1	781	81.4
1207	(6/)	5.45	101.6	14.6	2.0	13.70	2.4	1,530	76.1
1208	(6/)	5.90	109.5	14.3	1.9	18.80	3.3	2,139	76.9
1209	(6/)	5.35	103.7	14.3	1.8	12,70	3.8	1,412	77.8
1210	(6/)	5.90	109.5	12.7	1.5	14.75	4.1	1,660	78.1

[1] Analyses made by E. M. Wood.
[2] Weight at start, 0.84 gram.
[3] Corn oil.
[4] Cottonseed oil.
[5] Cod-liver oil.
[6] Salmon oil.

the addition of these oils, and that the energy factor alone is not responsible. Corn oil may prove to be a useful tool in future studies of this nature because of its low vitamin content, utilization (as indicated by increased body fat and high iodine number of the fat deposited), and failure to alter the growth rate of the trout.

Gains alone should not be used in evaluating the effects of diets on growth. Corn-oil diets and the control diets produced the same gains; but it is felt, because of the higher fat content, that the trout which were fed corn oil actually gained less weight in terms of flesh produced. Even though trout fed the fish oil showed an increase in body fat, as compared with the controls, the greater gain in weight certainly demonstrated a correspondingly greater production of fish flesh. The oils in these instances were no doubt beneficial.

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* * *

Artificial propagation has shown marked success in saving from extinction two rare subspecies of trout, *Salmo beardslei* and *S. crescentis*. These trout, occurring in Lake Crescent, within the Olympic National Park, have been so heavily fished that their survival has seemed doubtful.

In the past 2 years, since the provision of the necessary facilities at the U. S. Fish-Cultural Station at Quilcene, Washington, the Fish and Wildlife Service has taken spawn at Lake Crescent, transported the eggs to Quilcene, and there produced numbers of these trout for return to the lake.

GPO 83-25433

Haddock Prediction for 1951 Proves Accurate

By Howard A. Schuck, U. S. Fish and Wildlife Service

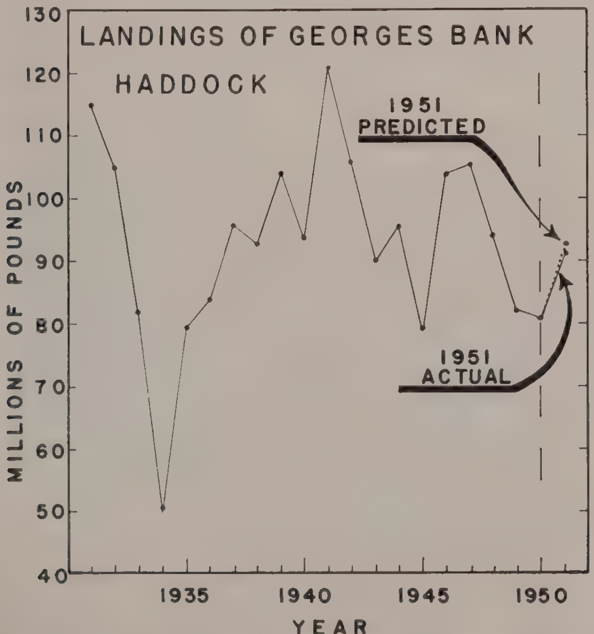
THE method of predicting the catch of haddock from Georges Bank a year in advance which was developed by the Woods Hole, Mass. Fishery Laboratory, proved 98.4 percent correct as regards the 1951 haddock landings. The method is dependent on the analysis of detailed data which have been collected routinely by the Fish & Wildlife Service since 1931.

Required for this analysis are the statistics of catch, including especially measures of the effort expended in making these catches, and data on the age composition and on the lengths and weights of the haddock landed over a period of years. The method depends on establishing the relation of the decline in abundance of each age group between succeeding years, together with establishing the variations in abundance of the several age groups contributing to the fishery. Once these relations have been established, it is possible to predict the landings for any year, providing data on the landings and on the age composition of the year preceding are available.

Although it has not yet been possible to present the full details of this method, it has been used to predict the Georges Bank haddock catch. This was made by Dr. William F. Royce to the National Fisheries Institute at their 1951 annual meeting in Boston, Mass. The prediction was for the "haddock year" of 1951, which differs by one month from the calendar year. The 1951 haddock year began February 1, 1951, and ended January 31, 1952.

It was predicted that a considerably greater catch would be made from Georges Bank in 1951 than the 80.5 million pounds landed in 1950. Just how much increase could be expected over 1950 obviously depended upon how much fishing would be done on Georges Bank in 1951. Thus, predictions were made for each of several fishing intensities.

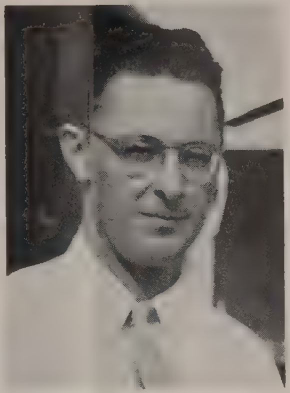
If, in 1951, the amount of fishing on Georges Bank was the same as in 1950, the catch to be expected was set at 88 million pounds; for a 10 percent increase in fishing effort, the prediction was set for 93 million pounds; and for a 10 percent decrease in effort, a catch of 83 million pounds was anticipated.



Graph showing Georges Bank haddock landings in millions of pounds for the 20-year period 1931-1950, and the predicted and actual 1951 production.

Size Also Predicted

Now that the 1951 haddock year is over, it is possible to make an evaluation of the prediction. But, of course, the evaluation at this time is not absolute since only estimates for the last two months of the landings are available.



Howard A. Schuck, fishery research biologist stationed at the Woods Hole, Mass. Fish & Wildlife Service laboratory.

The records show that there were 9.7 percent more days fished in 1951 than in 1950. With this increase in fishing, the catch was predicted to be 92.8 million pounds. Actually, 91.3 million pounds were landed. Thus the landings differed from the prediction by only 1.5 million pounds. The prediction proved 98.4 percent accurate.

A prediction also was made of the size of haddock to be expected in the landings. It was predicted that "a larger than usual percentage of the 1951 catch would be good-sized scrod, averaging about 2¼ pounds".

In the average year haddock weighing about 2¼ pounds (2 to 2½ pound range) have accounted for approximately 29 percent of the landings. For 1951, all of the size composition data are not yet analyzed, but for 7 trips to sea made by Service biologists these data are available. Fully 43 percent of the landings from these trips were composed of 2 to 2½ pound fish. Thus, as predicted, considerably more of this size group were taken than are taken in an average year.

Encouraged by the fact that the actual landings closely approximated the predicted catch, we are now in the process of making the second annual prediction—that for 1952.

(Reprinted from Atlantic Fisherman, March 1952 issue)

Predict More Large Haddock from Georges Bank

Fewer Scrod Haddock, with Slight Decline In Total Catch, Anticipated by Howard A. Schuck, Fish & Wildlife Service Biologist

FOR the past 25 years the stock of haddock most important to United States fishermen has been that on Georges Bank. During this time Georges Bank has produced annually as much as 223 million pounds (in 1929), and as little as 50 million pounds (in 1934). Since 1934 production has fluctuated between 78 and 122 million pounds. These fluctuations in catch have always been a cause of concern to the fishermen and have contributed to crises in the fishing industry. Since 1945 the abundance of Georges Bank haddock has declined. Also, the proportion of "large" to "scrod" haddock dropped to an all-time low in 1950.

The question in everyone's mind at that time was whether this downward trend would continue or whether the stocks would again increase. For many years it has been considered highly desirable to be able to predict the future ups and downs in the haddock population.

Early in 1951, after several years of intensive study of the Georges Bank haddock population, a method of prediction was developed.

The first annual prediction was made for the year 1951. This was made in April 1951, but was based entirely on data collected during 1950. This prediction was for the haddock year, that is, for the 12-month period beginning February 1, 1951 and ending January 31, 1952. When the returns were in for the 1951 landings, it was found that the prediction had been remarkably accurate. As reported in the March 1952 issue of ATLANTIC FISHERMAN, the Georges Bank haddock catch was predicted to be 92.8 million pounds. Actually about 91.3 million pounds were landed. Thus the prediction was 98.4 percent correct. The landings represented a considerable increase over the 80.5 million pounds landed in 1950.

The detailed analysis of last year's data is now completed and the second prediction can be made—for the haddock year 1952. It is presented here as a service to the fishing industry of New England.

Before we make this second prediction, however, it is appropriate to mention certain trends in the Georges Bank haddock fishery which largely determine next year's fishing. For the past two years the fishery has been maintained very largely by one single brood of fish—those hatched in 1948. As 2-year-olds in 1950, this brood contributed over 38.4 million pounds of the total of 80.5 million pounds (or almost 48 percent) of all 9 ages landed. As 3-year-olds in 1951 this same brood contributed over 49.0 million pounds of the total of 91.3 million pounds (or almost 54 percent) of all ages landed. The tremendous importance of this one brood to the fishery is thus apparent. In fact, it may be said that there would have been extremely poor fishing on Georges Bank during the past two years if it were not for the brood of 1948. Now this big brood is not completely decimated. They will contribute in 1952; but their peak of contribution was passed as 3-year-olds in 1951.

Typical of trawlers which fish for haddock from Georges Bank is the 106' "Esther M.", shown unloading at Boston Fish Pier. She is operated by Standard Fish Co., skippered by Capt. Victor Greene, and powered by a 550 hp. supercharged Atlas Diesel.

Obtaining scale samples from haddock being landed—an operation necessary in determining abundance of various ages.

Of the other broods now in the fishery, those which were 4-, 5-, 6-, 7-, 8-, and 9-year-olds in 1951 will also be less abundant in 1952 than they were in 1951; but those which were 1- and 2-year-olds will be more available than they were in 1951. Neither of these two young broods (those spawned in 1949 and 1950) are of particularly large proportions however. The measures of their strength that we have to date indicate that they are only of average magnitude, or slightly below average. Thus they cannot be counted upon to contribute to the extent that their predecessor (brood of 1948) did when it was 2 or 3 years of age.

Furthermore, there will be one brood affecting the 1952 fishing which had no effect in 1951, that is, those which were 0-year-olds in 1951 and which will be 1-year-olds in 1952. We do not have a precise measure of the magnitude of this brood but 1-year-olds as such are never very important to the fishery. They contribute an average of only 0.6 million pounds per year and have never contributed more than 2.6 million pounds, thus they cannot affect the outcome in 1952 very much.

The net effect, after considering the poundages and relative numbers of the different ages involved, is that increases in the fishable stocks of the younger ages will not compensate for decreases in the stocks of all older ages, thus a smaller fishable stock will be available on Georges in 1952 than in 1951. Under present conditions of fishing, a decline in landings per boat day is inevitable.

The degree to which total landings will decline depends, of course, on how much fishing is actually done. If the amount of fishing is the same in 1952 as in 1951, we predict that landings for 1952 will be about 89.0 million pounds, a reduction of 2.3 million or 2.5 percent from last year's catch.

It appears, however, that less fishing may be done on

(Continued on other side)

Reprinted from May 1952 issue of Atlantic Fisherman

Georges Bank than last year, as fish are abundant on the Nova Scotia banks and considerable fishing time may be spent there instead of on Georges. We are able to make predictions to cover this situation also. For instance, if the amount of fishing on Georges declines 10 percent, we estimate the catch will be about 84.0 million pounds; if it declines 20 percent, the catch will be about 79.0 million pounds; and if it declines 30 percent, the catch will be about 74.0 million pounds.

Although an increased amount of fishing on Georges does not appear likely in 1952, we estimate that for a 10 percent increase in fishing effort about 94.0 million pounds will be landed, for a 20 percent increase in effort about 99.1 million pounds will be landed.

Due to the inherent variability of fishery data, it is too much to expect that these predictions will prove 100 percent accurate. However, if no major changes occur in the fishing habits of the fleet or the schooling habits of the fish, the chances are better than 2 out of 3 that actual landings will not deviate from the predicted by more than about 8 percent.

Although the landings of haddock from Georges Bank in 1952 are expected to decrease if fishing effort remains the same, the size of fish landed will be greater than during the past two years. In 1950, haddock averaged smaller than in any previous year (1.86 pounds per fish). In 1951 there was a partial recovery (to 2.13 pounds per fish) and in 1952 the average weight will be even greater. Furthermore, a larger proportion than usual will be in the 2½ to 3½ pound range.

We also predict that, for the first time in 3 years, the ratio of "large" to "scrod" will return to the more normal condition, that is, landings of large will again exceed landings of scrod.

Not only will the proportion of large haddock to scrod increase in 1952, but the actual landings of large haddock will be greater than in 1951 and the actual landings of scrod will be less than in 1951, provided the fishing effort is about the same as last year.

This, then, is the situation to be expected on Georges Bank in 1952 if fishing methods remain the same as they have been over the past 20 years, our prediction of the future having been based upon experiences and events of this span of years. If, however, the method of fishing changes appreciably, as it will, for instance, if the proposed minimum mesh regulation becomes effective during the year, then obviously these predictions would not apply.

FURTHER STUDIES ON FACTORS DETERMINING TISSUE LEVELS OF SULFAMERAZINE IN TROUT

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Abstract

There is considerable variation in the tissue level of sulfamerazine among individual trout in a treated population. This fact may be the reason why prolonged sulfonamide therapy sometimes fails to free all trout from *Bacterium salmonicida.* The quantity of food given with a standard dosage of sulfamerazine has a pronounced effect on the tissue concentration of sulfamerazine; the concentration increased when the quantity of food decreased. It appears therefore, that trout should be fed at a rate very closely adjusted to their optimum feeding requirements for the best practical results. The start of treatment with high initial doses of sulfamerazine had no effect on the tissue concentration sustained by the maintenance dosage. The relative distribution of sulfamerazine in various organs and tissues of rainbow trout was about the same as in brown and brook trout. The only difference noticed was the lack of peak levels of short duration between the 8 and 10 days of treatment, which is characteristic for brook and brown trout.

Introduction

The initial studies on the distribution of sulfonamides in trout tissues were described in a previous paper (Snieszko and Friddle, 1951). These investigations were designed to gain a better understanding of the therapeutic action of sulfonamides which are being used in the treatment of furunculosis and certain other bacterial fish diseases. The present study is an extension of the original work. Sulfamerazine was the only sulfonamide tested in these experiments because it is the drug of choice in chemotherapy of fish diseases. Limitations in time and facilities made it impossible to carry out parallel tests with other sulfonamides. The methods of investigations were the same as those previously described, and all trout used were maintained in water having a temperature of 12° to 14° C. (53° to 57° F.).

Variation in the Tissue Concentration of Sulfamerazine

In all previous tests described, sulfamerazine levels were determined for composite samples made from several fish. In this experiment the determinations were made for individual trout to determine the degree of variation in the sulfonamide tissue level. The trout used in these experiments were taken at random from a treated population.

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Fingerling brook trout (average weight 53 grams) were distributed in 4.5-kilogram lots in two troughs. They were fed twice daily at a rate of 4 percent of the fish weight. The dosage of sulfamerazine was 20 milligrams per 100 grams of trout per day. It was evident that in a population of trout which were fed at the usual rate, there was considerable variation in the sulfamerazine tissue level among individual fish (Table 1, Figure 1). Even after 6 or 12 days of treatment, trout were found with only traces of sulfamerazine in their tissues. This observation may help to explain why prolonged sulfonamide therapy sometimes fails to free all trout from *Bacterium salmonicida* in an infected population.

TABLE 1. — *Tissue concentrations of free sulfamerazine in individual fingerling brook trout (average weight 52.5 grams) treated at a rate of 20 milligrams of sulfamerazine per 100 grams of fish per day—expressed in milligrams percent.*

Days from start of treatment	Replicates						Average (A to F)
	A	B	C	D	E	F	
1	4.7	4.5	0.0	2.6	4.3	2.3	3.1
2	2.6	5.7	9.2	4.9	5.1	5.7	5.5
3	4.3	5.7	2.2	2.6	4.7	7.7	4.5
4	1.8	4.9	5.7	1.8	5.5	3.6	3.9
5	7.7	4.2	5.4	6.1	5.9	7:4	6.1
6	2.1	6.2	6.0	2.1	0.2	7.2	4.0
7	7.9	7.9	6.3	6.1	5.9	6.3	6.7
8	10.0	6.5	6.5	7.8	10.8	8.2	8.3
10	6.1	8.4	8.7	9.4	4.5	5.5	7.1
12[1]	5.9	7.7	7.4	7.7	0.2	6.0	5.8
14	1.4	7.2	7.2	6.1	4.9	4.1	5.2
15	2.3	2.4	1.6	2.0	0.5	3.8	2.1
16	0.5	0.4	0.5	0.1	0.1	0.6	0.4

[1] Treatment was stopped on the 13th day.

The wide variation in tissue levels of sulfamerazine among individual fish could be ascribed to: (a) unequal intake of food by individual fish, (b) unequal distribution of the drug in the diet, (c) individual variation in the rate of absorption or elimination of sulfonamides, or (d) any combination of the above.

In order to determine how much variation existed in the tissue concentration of trout which had been given identical doses of sulfonamide, yearling brook trout *(Salvelinus fontinalis)*, brown trout *(Salmo trutta)*, and rainbow trout *(Salmo gairdnerii)*, weighing on the average 55, 65, and 53 grams per fish respectively, were given sulfamerazine in single doses at a rate of 10 milligrams per 100 grams of trout per day. The drug was carefully weighed, distributed in gelatin capsules, and introduced into the stomach of fish. Tissue concentrations of free sulfamerazine were determined for different individual trout for several days following the administration of the drug and results (Table 2) indicate that there was a wide variation. The fish did not receive food during the experiment. It is interesting to note that the rate of absorption was somewhat lower and slower with brook trout and the rate of elimination was fastest with brown trout.

QUANTITY OF MEDICATED FOOD AND THE TISSUE CONCENTRATION OF SULFAMERAZINE.

Snieszko and Friddle (1951) noted that the tissue concentrations of sulfamerazine given at the same dosage were higher in older fish which were fed at a lower rate. This problem was studied further because it had practical significance.

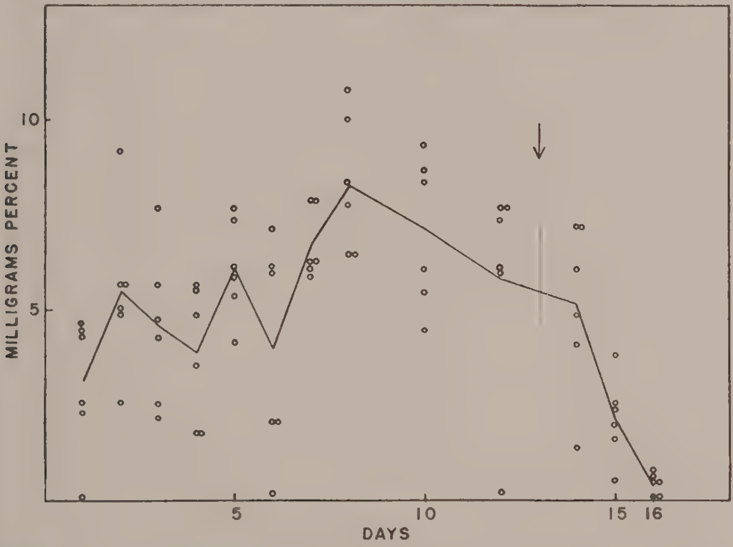

FIGURE 1. — Tissue concentrations of free sulfamerazine in individual fingerling brook trout (average weight 52.5 grams) treated at a rate of 20 milligrams of sulfamerazine per 100 grams of fish per day. Circles represent single fish, solid line the averages, and the arrow time when treatment was stopped.

Fingerling rainbow trout (average weight 27 grams) were distributed in 1.5-kilogram batches among six experimental troughs. The fish in each pair of troughs were fed at the rate of 2, 4, and 8 percent of fish weight per day. Sulfamerazine was added to all diets at a constant level of 20 milligrams per 100 grams of fish per day. All of the food was taken immediately by those fish fed at the rate of 2 and 4 percent. An excess of food remained in the troughs containing fish fed at the 8 percent level. The results presented in Table 3 and Figure

2 are very interesting because the tissue concentration increased when the quantity of food decreased. The 4 percent feeding rate described by Duell, *et al.* (1942) was about correct for fish of this size. The excessive rate of feeding resulted in a generally low tissue concentration. It appears that trout should be fed at a rate very closely adjusted to their optimum feeding requirements for the best practical results.

TABLE 2. — *Tissue concentrations of sulfamerazine (milligrams percent) in trout treated with one dose of the drug introduced orally in capsules at the rate of 10 milligrams per 100 grams of fish. Determinations were made with composite samples of three trout.*[1]

Species	Time between treatment and examination				
	18-20 hours	2 days	3 days	4 days	5 days
Yearling brook trout..........	2.4 2.1 1.5	2.6 2.0 2.5	1.6 1.9 0.9	1.2 2.6 1.1	0.2 0.2 0.5
Average..................	2.0	2.4	1.5	1.6	0.3
Yearling brown trout..........	5.1 4.3 2.3	5.1 4.3 2.3	0.9 0.4 0.6	0.1 0.0 0.0	....
Average..................	3.9	3.9	0.6	0.03	....
Yearling rainbow trout........	3.1 5.5 4.2	4.0 2.3 2.8	1.4 1.4 1.1	0.4 0.6 0.4	0.1 0.1 0.8
Average..................	4.3	3.0	1.3	0.5	0.3

[1] Average weight of brook, brown and rainbow trout was 55, 65, and 53 grams respectively.

INITIAL AND MAINTENANCE DOSAGES OF SULFAMERAZINE

With humans and some domestic animals, it is an accepted practice to administer sulfonamides at a high initial dose and then to maintain a relatively high blood (tissue) concentration thereafter by administering smaller doses at frequent intervals (Northey, 1948).

To test the value of such a practice in the treatment of fish, the following experiment was carried out. Fingerling brook trout (average weight 33 grams) were distributed in 1.87-kilogram batches among six experimental troughs and fed at a 4 percent rate. The initial dosage of sulfamerazine was 30 milligrams per 100 grams of trout per day. On the 7th day of the experiment when the tissue concentration of sulfamerazine was already well leveled off, the trout were divided into three groups. Each group received sulfamerazine at a level of 30, 20, and 10 milligrams per 100 grams of fish per day. The results are presented in Table 4 and Figure 3. An initial dosage of 30 milligrams per 100 grams of trout per day produced an average tissue concentration of 9.2 milligrams percent. Lower dosage levels resulted in a correspondingly decreased sulfamerazine tissue concentration. By comparing this set of data with the results obtained from another experiment (Table 3, Figure 2), it is evident that the high initial dose (30 milligrams) apparently had no greater effect on the tissue concentration than that level obtained only by treatment with the maintenance dosage of 20 milligrams per 100 grams of fish per day.

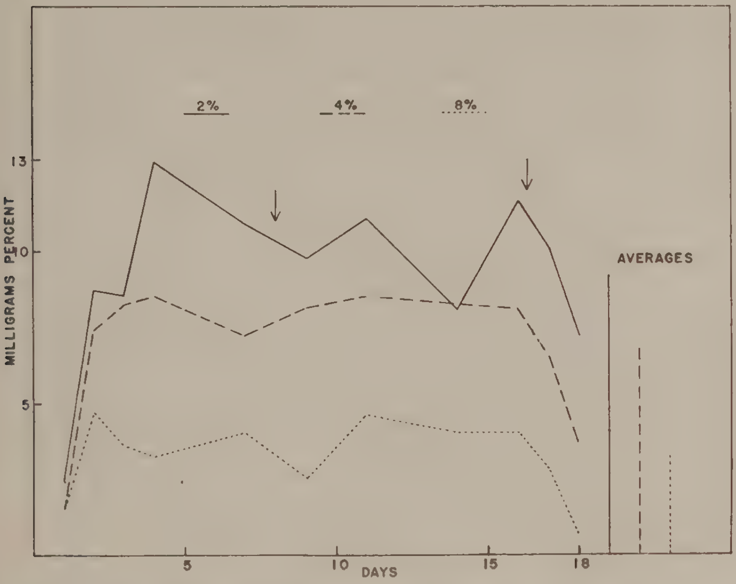

Figure 2.—Relationship between rate of feeding and tissue concentrations of sulfamerazine (milligrams percent) in fingerling rainbow trout (average weight 27 grams). Fish were fed at the rates of 2, 4, and 8 percent of their weight per day. Sulfamerazine was administered at a rate of 20 milligrams per 100 grams of fish per day. The left arrow indicates time of a quantitative adjustment of diets and of drug, and the right arrow end of treatment.

Distribution of Sulfamerazine in Tissues of Rainbow Trout

Snieszko and Friddle (1951) showed the distribution of sulfamerazine in various tissues of brook and brown trout. It was believed advisable to study the distribution of sulfamerazine in the tissues of rainbow trout since this species, in contrast to the other two, responded differently to both feeding with sulfamerazine (Gutsell and Snieszko, 1949) and to treatment with pyridylmercuric acetate (Rodgers, *et al.*, 1951). Fingerling rainbow trout (average weight 40 grams) were distributed in 2-kilogram lots among three experimental troughs. They were fed at a rate of 3 percent by weight and received sulfamerazine at a level of 20 milligrams per 100 grams of fish per day. Determinations were made on composite samples of six fish, two from each trough. The results are presented in Table 5.

The blood and liver contained the highest concentration of sulfamerazine. The level was somewhat lower in the kidney and lowest in the muscle tissue. The concentration of sulfamerazine in rainbow trout gradually increased during the experiment without reaching a peak level between the 8th and 10th day of treatment. This is in contrast to the results obtained in experiments involving brook and brown trout[1] (Snieszko and Friddle, 1951). It should be noticed that after each adjustment of the quantity of drug and diet, there was some increase in the drug concentrations. This could be explained on the basis of the observations noted in the present study relating to the effect of the quantity of food on the tissue levels of sulfamerazine (Table 3, Figure 2).

TABLE 3.—*Relationship between rate of feeding and tissue concentrations of sulfamerazine (milligrams percent) in fingerling rainbow trout (average weight 27 grams)—determinations made with duplicate samples (A and B) of three fish each.*

Days after start of treatment	Feeding rate (percentage of fish weight per day)					
	2		4		8	
	A	B	A	B	A	B
1	4.7	0.2	2.4	0.2	2.1	1.2
2	10.0	7.4	7.4	7.4	4.9	4.5
3	11.7	5.5	8.2	8.2	3.6	3.6
4	14.4	11.4	8.2	8.9	3.2	3.2
7[1]	10.0	11.7	6.8	7.7	3.2	4.9
9	11.1	8.4	7.7	8.6	2.8	2.2
11	11.4	10.6	9.7	7.4	4.0	5.3
14	7.7	8.4	8.2	8.2	3.4	4.7
16[2]	12.5	10.8	7.0	9.2	3.8	4.3
17	10.3	10.0	7.2	5.7	2.8	2.8
18	6.8	7.7	4.9	2.3	0.8	0.4
Average concentration	10.1	8.4	7.0	6.7	3.1	3.4

[1] Rates of feeding and treatment were adjusted on the 8th day.
[2] Treatment was discontinued on the 16th day.

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[1] This fact by itself probably would be of little significance. However, other authors made interesting observations on some biochemical and physiological differences existing among various species of trout. For example, the growth rate of rainbow, brook, and brown trout are differently affected by sulfamerazine (Gutsell and Snieszko, 1949), pyridylmercuric acetate is toxic to rainbow trout (Rodgers, *et al.*, 1951), and requirements of biotin are different in various species of trout (Phillips, *et al.*, 1947).

RECOMMENDATIONS FOR TREATMENT

In the first paper of this series the authors discussed the importance of pharmacological investigations on the distribution of sulfonamides in trout tissues. This procedure was proposed as a rational approach to the use of sulfonamide therapy for some infectious diseases. Therefore, the present discussion will concern only those problems which are directly connected with the results presented here.

When a population of fish suffering from an epizootic is treated with sulfonamides not all of the fish receive the drug in amounts which are directly proportional to their body weight. Those which are too sick will not take any food, and smaller and less aggressive individuals will get less than the average amount of available feed. The data presented in Table 1 and Figure 1 show that even in a population of well graded, apparently normal, and adequately fed fish, there is great variation in the tissue concentration of sulfamerazine. Even when the drug

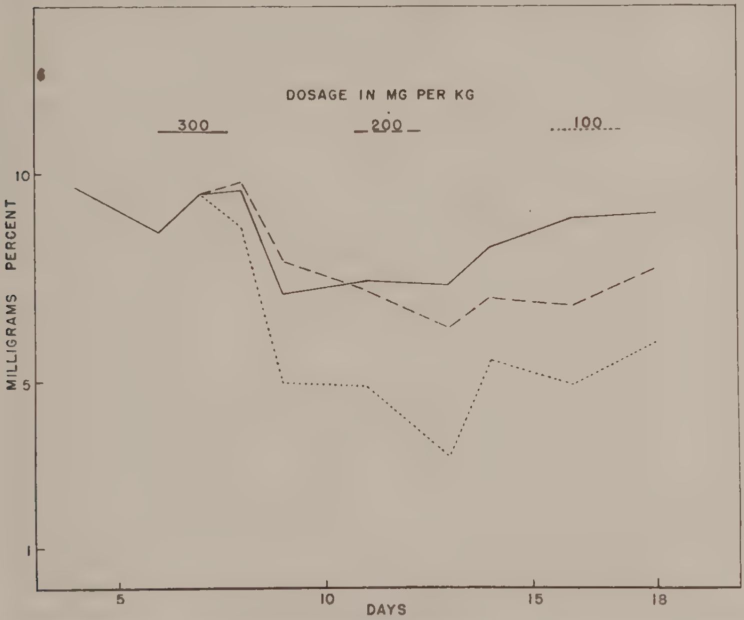

FIGURE 3.—Tissue concentrations in milligrams percent of free sulfamerazine produced by initial and maintenance dosages of this drug in normal fingerling brook trout. Dosages expressed in milligrams per kilogram of fish per day.

was introduced in carefully measured quantities into the stomach of the fish the range in the tissue concentration was much greater than could be accounted for by the experimental error (Table 2).

Another important aspect of sulfonamide therapy in fishes is the relation between the quantity of medicated diet fed and the tissue concentration of the drug (Table 3, Figure 2). The results clearly indicate that excessive feeding is wasteful and produces low tissue levels of sulfamerazine. Since the therapeutic effect of sulfonamides depends on the concentration present in blood and other tissues, it follows that excessive feeding is undesirable. The low feeding rate produced high tissues concentrations of sulfamerazine, but the range of variation in the tissue concentration was also greatest. Therefore the advantage of high tissue concentration in fish fed at a low rate would be offset by the fact that all weak fish, which probably would need the drug most, would be deprived of it because of the smaller quantity of available food. Therefore for best results, the treated fish should be well graded, their total weight should be known, and the quantity of food should be correctly adjusted to the nutritional requirements of fish of this size. Feeding slightly deficient amounts of food may be preferable to excessive feeding.

TABLE 4—*Tissue concentrations (milligrams percent) of free sulfamerazine (total sulfamerazine in parentheses) produced by initial and maintenance dosages (per 100 grams of fish per day) of this drug in normal fingerling brook trout (average weight 33 grams)—determinations made with composite samples of three trout each.*

Consecutive days of treatment	Replicate troughs					
	A	B	A	B	A	B
	Initial dosage (milligrams) first 7 days of treatment					
	30	30	30	30	30	30
4	10.3	11.2	8.7	11.1	8.9	7.9
6	8.2	7.4	8.4	8.4	9.2	9.8
7	9.2	9.2	8.2	11.4	9.4	9.4
Average 4 to 7 days	9.2	9.2	8.4	10.3	9.1	9.0
	Maintenance dosage (milligrams) remaining 11 days of treatment					
	30	30	20	20	10	10
8	10.0	9.2	9.4	10.3	9.2	8.2
9	6.1	8.2	8.4	7.5	4.3	5.7
11	6.5(8.9)	8.4(9.4)	7.4(8.8)	7.1(8.2)	4.3(5.7)	5.5(6.3)
13	7.2	7.4	5.9	6.8	3.8	2.6
14	8.2(8.6)	8.2(8.6)	7.9(8.2)	6.1(6.8)	5.5(5.9)	5.5(5.9)
16	9.2(9.4)	8.6(9.2)	7.9(8.2)	5.7(6.3)	4.9(5.7)	4.9(5.1)
18	9.4(10.0)	8.6(8.4)	6.8(7.2)	8.6(8.9)	5.7(7.0)	6.1(6.1)
Average 8 to 14 days	8.1	8.4	7.7	7.4	5.4	5.5

The present experiments also indicate that high initial doses do not appear to have any significant effect on the tissue concentrations of sulfamerazine sustained by the maintenance doses. Within 2 or 3 days after the start of treatment, the dosage of 20 milligrams of sulfamerazine per 100 grams of fish per day (9 grams per 100 pounds) results in a tissue concentration of 7 to 8 milligrams percent and a blood level of 12 to 14 milligrams percent. These concentrations were determined to be entirely satisfactory in the treatment of furunculosis.

TABLE 5.—*Sulfamerazine concentrations (milligrams percent) in various tissues of fingerling rainbow trout (average weight 40 grams) treated at a rate of 20 milligrams of the drug per 100 grams of trout per day — determinations made with composite samples of 6 fish each.*

Days after start of treatment	Tissue			
	Muscle	Blood	Liver	Kidney
1	2.8	5.5	7.0	4.5
2	4.3	8.2	7.7	6.5
3	6.3	12.0	12.0	10.0
4	7.4	12.0	13.4	10.6
7[1]	6.5	11.4	13.2	10.3
9	9.4	15.4	15.0	13.4
11	8.9	14.6	14.6	13.2
14[1]	8.4	14.3	14.0	12.4
16	10.0	16.4	15.4	14.6
18	9.4	17.3	16.0	15.0
21[2]	8.2	14.6	14.6	11.7
22	2.9	5.5	5.9	4.7
23	1.5	2.8	4.2	2.4
24	0.4	0.9	1.8	1.1
Average 4 to 21 days	8.5	14.5	14.5	12.6

[1] Quantities of diet and drug were adjusted to weight of fish.
[2] Treatment was discontinued.

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HARD-CLAM FISHERY OF THE ATLANTIC COAST

By Richard E. Tiller,* John B. Glude,** & Louis D. Stringer**

(Prepared at the request of the Atlantic States Marine Fisheries Commission)

INTRODUCTION

This report supplements biological studies being conducted by the U. S. Fish and Wildlife Service's Clam Investigations, and deals with the present status and past trends of the fishery for the hard clam or quahaug (Venus mercenaria),[1] the types of gear employed, and the particular problems facing the industry in each of the Atlantic coastal states.

The information on which the study is based was obtained from personal interviews during 1949, 1950, and 1951 with clam fishermen, dealers, and state conservation personnel in all of the Atlantic Coast states; and from the Service's catch statistics. The results of these surveys have been used in planning and establishing the clam research program authorized by Congress in 1948.

Members of state conservation agencies, universities, and research groups contributed information used in this report. Dealers and fishermen have been thoroughly cooperative in describing the industry and its problems. The first part of this report is a consideration of the general aspects of the fishery, including data pertaining to volume and value of production, location of the fishing grounds, and a description of the types of gear employed. The second part includes state summaries, and deals more in detail with the production and problems of the individual states. Catches statistics have been taken from the U. S. Fish and Wildlife Service's Administrative Reports or Statistical Digests.

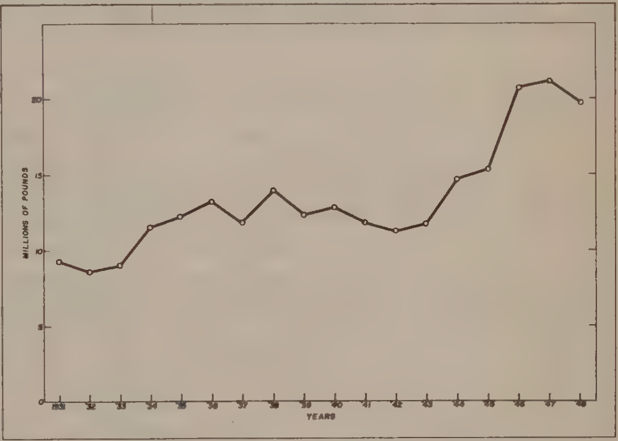

FIG. 1 - TOTAL CATCH OF HARD CLAMS FOR ATLANTIC COAST STATES, 1931-48. WHEN STATISTICAL SURVEYS WERE INCOMPLETE, THE ANNUAL TOTALS WERE CALCULATED FROM AN AVERAGE OF PRECEDING AND SUCCEEDING YEARS.

GENERAL ASPECTS OF THE FISHERY

CATCH AND VALUE: Although Atlantic Coast catch statistics for hard clams from 1931 to 1948 show a steady upward trend in production to a level above previous peak years (table 1 and figure 1), the total annual production and value are small

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[1] THIS DOES NOT INCLUDE THE OCEAN QUAHAUG (ARCTICA ISLANDICA).

Table 1 - Production (Meats) and Value of the Atlantic Coast Hard-Clam Fishery, 1931-48

Year	Maine	Mass.	R. I.	Conn.	N. Y.	N. J.	Del.	Md.	Va.	N. C.	S. C.	Ga.	Fla.	Total
	QUANTITY (In Thousands of Pounds)													
1948	289	1,495	3.512	21	7,271	4,007	158	200	1,567	*	*	*	*	18,520**
1947	96	1,967	3,139	58	10,331	3,226	9	250	879	*	*	*	*	19,955**
1946	168	2,277	3,035	106	6,740	*	*	183	979	*	*	*	*	15,488**
1945	489	2,296	1,911	42	3,402	4,838	31	119	1,010	502	1	-	691	15,332
1944	186	1,810	1,522	24	6,818	2,094	26	180	834	*	*	*	*	13,494**
1943	79	1,560	1,305	38	4,133	1,933	33	*	*	*	*	*	*	9,081**
1942	152	1,844	2,004	39	2,250	1,802	13	160	1,672	*	*	*	*	9,936**
1941	*	*	*	*	*	*	*	111	1,563	*	*	*	*	1,674**
1940	5	2,411	1,978	59	2,808	2,366	33	79	1,764	530	3	-	708	12,744
1939	-	2,509	2,015	179	2,223	1,842	36	67	2,025	629	-	-	813	12,338
1938	55	2,299	2,164	211	2,243	2,925	24	53	2,810	358	-	-	747	13,889
1937	13	1,311	2,281	204	2,531	2,523	24	64	1,631	430	8	-	748	11,768
1936	*	*	*	*	*	*	47	48	2,625	840	20	-	634	4,214**
1935	2	1,266	2,360	429	1,645	3,464	108	25	1,644	*	*	*	*	10,943**
1934	*	*	*	*	*	*	*	32	2,609	338	47	-	535	3,561**
1933	12	1,769	1,158	102	1,945	1,476	201	42	1,169	*	*	*	*	7,874**
1932	135	1,806	1,312	206	885	1,356	30	27	1,484	261	5	1	1,121	8,629
1931	198	2,928	1,565	120	1,265	1,356	25	2	742	332	-	1	794	9,328
Total ..	1,879	29,548	31,261	1,838	58,490	35,208	798	1,642	27,007	4,220	84	2	6,791	198,768**
Year	VALUE (In Thousands of Dollars)													
1948	60	478	1,114	9	2,424	1,603	63	100	783	*	*	*	*	6,634**
1947	28	591	827	25	3,444	1,119	3	125	439	*	*	*	*	6,601**
1946	30	666	737	27	2,921	*	*	128	667	*	*	*	*	5,176**
1945	92	675	524	15	2,068	1,629	9	62	525	151	-	-	173	5,923
1944	42	470	347	8	3,341	679	8	90	378	*	*	*	*	5,363**
1943	14	435	274	13	2,468	628	9	*	*	*	*	*	*	3,841**
1942	22	348	410	9	730	558	3	49	554	*	*	*	*	2,683**
1941	*	*	*	*	*	*	*	25	339	*	*	*	*	364**
1940	-	336	237	10	479	340	4	17	352	45	-	-	67	1,887
1939	-	352	236	22	341	269	5	13	338	50	-	-	79	1,705
1938	4	263	183	44	393	376	3	10	375	28	-	-	72	1,751
1937	1	110	288	43	442	431	3	12	271	34	-	-	49	1,684
1936	*	*	-	*	*	*	7	5	407	75	2	-	41	537**
1935	-	143	219	89	281	500	13	3	371	*	*	*	*	1,619**
1934	*	*	*	*	*	*	*	3	364	34	6	-	26	433**
1933	1	215	137	21	276	224	32	4	264	*	*	*	*	1,174**
1932	14	198	163	48	147	201	7	5	348	17	1	-	43	1,192
1931	18	391	252	38	407	326	5	1	253	31	-	1	36	1,759
Total ..	326	5,671	5,948	421	20,162	8,883	174	652	7,028	465	9	1	586	50,326

*NO STATISTICAL SURVEY **INCOMPLETE

when compared with other shellfish resources of the Atlantic States. In value per pound of shucked meats, however, hard clams outrank all others except lobsters. A summary of the production and value of the shellfish resources based on Fish and Wildlife Service catch statistics for 1945 (the most recent year for which complete data are available) is presented in table 2.

Table 2 - Shellfish Resources of the Atlantic Coast States, 1945

Species	Quantity	Value	Avg. Price per Pound
	1,000 Lbs.	$1,000	¢
Blue crab (in shell)	60,258	4,293	7
Shrimp (heads on)	55,947	4,227	8
Oyster (meats)	52,920	19,383	37
Lobsters (Northern, in shell)	22,727	9,460	42
Hard clam (meats)	15,332	5,923	39
Soft clam (meats)	8,875	1,954	22
Scallop (meats)	6,619	2,399	36

LOCATION OF THE FISHERY: Hard clams occur in nearly every sheltered bay, cove, or inlet along the entire Atlantic Coast, but the fishery is centered largely in the southern New England and Middle Atlantic States. New York leads in production, followed in descending order by New Jersey, Rhode Island, and Massachusetts. On the basis of a five-year average (1944-48), these four states produced 85 percent of the hard clams caught on the entire coast (figure 2). Virginia, Florida, and North Carolina are the ranking southern states and account for an additional 13 percent.

The locations of the commercially-fished areas along the Atlantic Coast are shown in figures 3, 6, 8, and 10. The coast has been divided into the four sections as follows:

New England - Maine, New Hampshire, Massachusetts, Rhode Island, and Connecticut.
Middle Atlantic - New York, New Jersey, and Delaware.
Chesapeake - Maryland and Virginia
South Atlantic - North Carolina, South Carolina, Georgia, and Florida.

TYPES OF GEAR AND PRODUCTION METHODS: The usual habitat of the hard clam is in relatively shallow water, and the fishery therefore lends itself quite well to hand-operated gear. Where the beds are exposed at low tide, or covered by only very shallow water, short-handled hoes or rakes are used almost entirely. Typically a New England gear, hoes are rarely used south of Rhode Island. The design varies somewhat from one locality to another, but the usual style is about two feet in length and is provided with four or five flattened tines 8 to 10 inches long as shown in figure 5. Forks and picks replace hoes in the southern states. These are basically the same in design, but have somewhat longer handles, and picks usually have only two or three closely spaced short tines.

In deeper water, long-handled rakes and tongs are employed. Rakes are used in all of the coastal states, and vary in pattern from one area to another, depending on the depth of water, type of bottom, and preferences of the local fishermen. Bull rakes, typically used in New England, are provided with detachable heads, 3 to 4 feet in width, fitted with closely-spaced curved teeth which form a horizontal basket. Spacing of the teeth varies according to the minimum legal size in the different states (figure 7).

Long sectional wooden handles or stales are fitted to the rake heads, the length depending on the depth fished, and the strength and skill of the fishermen. Occasional reports were obtained of stales over 50 feet long, although 36 feet is usually the maximum length. In fishing, the rake is shoved out and away from the anchored boat, and then worked through the bottom in a series of short tugs to a vertical position, from which it is hauled up. The long curved teeth force a roll of bottom soil ahead of them as the rake is pulled, and the clams are held, while the soil is washed through. Generally, the use of rakes is restricted to softer bottom than that which can be fished with tongs.

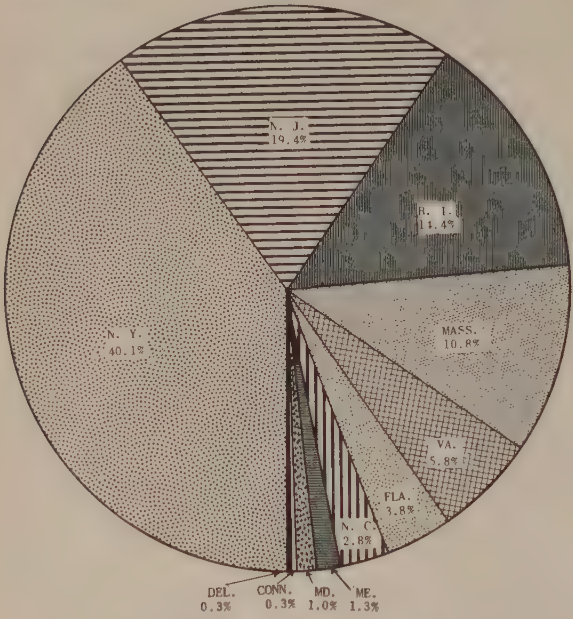

FIG. 2 - AVERAGE HARD-CLAM PRODUCTION BY STATES, 1944-48, EXPRESSED IN PERCENT.

Basket rakes, on which the ends are closed by wire mesh are used in some localities, particularly where clams are abundant. They are very popular in Massachusetts for the recovery of planted clams from privately-leased grounds.

Tongs (figure 9) are extensively used in all states except Florida, and accounted for over 60 percent of all the hard clams caught in the coastal states during the period from 1944 to 1948. Basically, tongs are a basket formed by two opposing sets of teeth, which are opened and closed by means of long scissor-like handles. The operating principle of tongs restricts their use to more shallow water than that which can be fished with rakes. Tong shafts over 28 feet in length are rarely used and in most cases do not exceed 18 to 20 feet.

Dredges are more varied in their design than any other type of clam gear. Different types are used in the power-boat fishery of Massachusetts and Rhode Island, as shown in figure 4, than in the sail fishery of New Jersey. The modified crab and oyster dredges used in lower Chesapeake Bay are of a still different pattern. Conservation laws in the different states regulate the size, weight, spacing and length of teeth and other features in the design of dredges.

The five-year (1944-48) average annual production and value by gear and by state are shown in table 3 and figure 11.

Table 3 - Five-Year (1944-48) Average Annual Catch of Hard Clams By Gear and State

State	TONGS		RAKES		DREDGES		BY HAND		HOES		CRABS		TOTAL	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	1,000 Lbs.	$1,000	1,000 Lbs.	$1,000	1,000 Lbs.	$1,000	1,000 Lbs.	$1,000	1,000 Lbs.	$1,000	1,000 Lbs.	$1,000	1,000 Lbs.	$1,000
Maine	-	-	-	-	-	-	-	-	246	50	-	-	246	50
Mass.	279	81	1,149	353	473	124	-	-	67	18	-	-	1,968	576
R. I.	1,405	396	366	105	853	210	-	-	-	-	-	-	2,624	711
Conn.	26	9	24	8	-	-	-	-	-	-	-	-	50	17
N. Y.	7,312	2,840	-	-	-	-	-	-	-	-	-	-	7,312	2,840
N. J.	1,158	405	1,104	397	147	55	424	149	-	-	-	-	2,833	1,006
Del.	5	2	20	8	20	7	-	-	-	-	-	-	45	17
Md.	76	42	84	47	2	1	25	13	-	-	-	-	187	103
Va.	503	266	341	181	53	29	157	83	-	-	-	-	1,054	559
N. C.	-	-	96	29	-	-	4	1	-	-	-	-	100	30
S. C.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ga.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fla.	-	-	1	-	103	26	-	-	9	2	25	6	138	34
Total	10,764	4,041	3,185	1,128	1,651	452	610	246	322	70	25	6	16,557	5,943
Percentage of Total	65.0	68.0	19.2	19.0	10.0	7.6	3.7	4.1	2.0	1.2	0.1	0.1	100.0	100.0

GENERAL REGULATORY MEASURES: It would be impractical to attempt a detailed discussion of conservation laws dealing with the hard clam in this report. The general regulations regarding size limits, gear limits, and closed seasons now in effect are summarized in table 4. These vary considerably from one state to another, and even within a single state, where individual townships have jurisdiction over the clam-producing areas within their boundaries. It should be understood that this table is simply a summary to aid the reader in understanding the meaning of sub-legal clams and to present some idea of the conservation measures being employed. It should not be used as a reference for state regulations.

Table 4 - Summary of General State or Local Regulations Governing the Hard-Clam Fishery of Atlantic Coast States

State	Minimum Size	Gear	Season
Maine	2" longest diameter	Regulated by each county or town.	Regulated by each county or town.
Massachusetts	2" longest diameter	Regulated by each town.	Regulated by each town.
Rhode Island	Nothing that will pass through a $1\frac{1}{2}$" ring.	Power dredges limited to Sakonnet River. No limit on hand gear.	Power dredges from Dec.1 to Mar.31. No season on hand gear.
Connecticut	Nothing that will pass through a $1\frac{1}{2}$" ring	No power gear on public grounds.	None
New York	1" thickness	No power gear on public grounds.	None
New Jersey	$1\frac{1}{2}$" in length	No power-operated vessel.	None
Delaware	None	No dredge more than 5 ft. 2 in. wide or with rings less than 2" in diameter.	None
Maryland	None	May be taken by rakes, tongs, patent tongs, dredges, or hand scrapes, as defined, and by no other means.	None
Virginia	None	Regulated in specific counties and sections.	None
North Carolina	$1\frac{1}{2}$" from hinge to mouth	Only with clam dredges, hand rakes, or by hand.	None
South Carolina	None	No dredging in less than 12' at low water.	Closed May 1 to Oct. 1.
Georgia	None	None	None
Florida	2" from hinge across widest part	None	None

TRADE CATEGORIES: Considerable variation in marketing procedures and size categories is encountered in different areas along the Atlantic Coast. A few general rules, however, apply to all areas.

The smallest legal-size hard clams--termed "necks," "little necks," or "steamer necks"--command the highest price in all areas. These small clams are used principally in restaurants, where they are served freshly opened on the half shell, or steamed and served with drawn butter.

The term "cherrystone" originated in the Chesapeake area in the vicinity of Cherrystone Creek, and refers to a clam slightly larger than the "little neck" classification common in New England. This size, too, is popular in most areas when served raw or steamed.

Clams larger than the cherrystone size are nearly always used in the preparation of chowders or in canned whole or minced clams, and are classed as "medium and "chowders." These larger sizes command a considerably lower price.

The manner in which clams are bought from the fishermen varies also from on area to another. Throughout New England and part of the Middle Atlantic area, clams are sold by weight or by bushel measure, although the weight of a bushel varies slightly from one state to another. This variation is due to the fact tha the yield in shucked meats of clams from upper New England is greater than from lower New England and the Middle Atlantic. In the Chesapeake and southern state the small, medium, and large clams are separated and sold according to the numbe per bushel.

MAINE

LOCATION OF THE FISHERY: Although small quantities are harvested for home consumption elsewhere along the coast, commercial fishing for hard clams is limit to a small area in upper Casco Bay, bounded on the east and west by the Harraseek and New Meadows Rivers, respectively. Maquoit Bay leads in production, and small amounts are taken from Quahaug Bay and sections of the New Meadows River.

GEAR AND METHODS: With the exception of entries for "dredges" in 1940 and 1942, "hoes" are the only gear listed in Fish and Wildlife Service records for t period 1931-48. Nearly all digging is in the intertidal zone, on beds exposed a

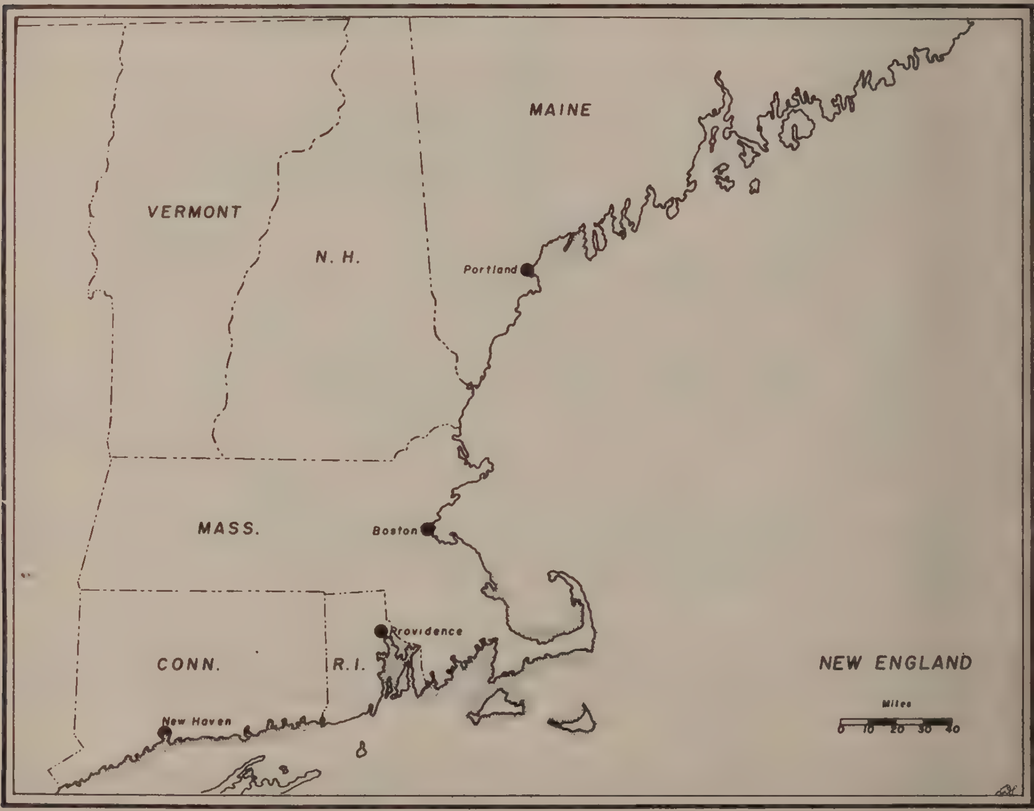

FIG. 3 - LOCATION OF HARD-CLAM FISHERY IN THE NEW ENGLAND STATES SHOWN BY STIPPLED AREAS.

low tide. Records of the Maine Department of Sea and Shore Fisheries show only four men fishing with tongs during 1950 in Maquoit Bay. A law passed in 1946 prohibits dredging from the flats or waters of Maquoit Bay.

GENERAL CONDITIONS OF THE FISHERY AND PROBLEMS: Sharp fluctuations in the annual catch have apparently occurred during the period from 1931-50, although catch records before 1942 are unreliable. According to the Maine Department of Sea and Shore Fisheries, an all-time peak was reached in 1949 and 1950, when the catch was nearly twice that of any previous year. This peak is based on a fishery for clams of one- or two-year classes.

The outlet for little necks and cherrystones is principally in the market areas of Boston, New York, and Philadelphia, and large chowders are sold to canneries in the southern New England and Middle Atlantic States.

Maine hard clams are considered particularly desirable for cannery use by some New England dealers, because the yield of shucked meats is greater than from clams in other areas.

During 1950, the Maine Department of Sea and Shore Fisheries undertook experimental transplantings of young quahaugs which had become established in such heavy concentrations that stunting and excessive mortality were occurring. Local fishermen volunteered assistance, and funds were made available by local buyers and dealers. In eighteen days, 3,012 bushels were moved to nearby commercially-depleted areas. Studies are being conducted by the State of Maine to determine if productive flats can be developed in other parts of the State.

Considering the relatively small area in which fishing is profitable, and the high level of production during the past three years, it appears that the hard-clam resources of Maine are being exploited to nearly their fullest extent. Unless successful techniques of restocking or farming are developed it is doubtful whether the fishery can expand much beyond its present production.

MASSACHUSETTS

LOCATION OF THE FISHERY: The southern shore of Cape Cod, Buzzards Bay, and the waters surrounding Nantucket, Martha's Vineyard, and the Elizabeth Islands support nearly the entire hard-clam fishery of Massachusetts. Wellfleet Harbor, near the northeast tip of the Cape, Barnstable Harbor, and Plymouth Bay also contribute to a lesser extent.

GEAR AND METHODS: Rakes are the most numerous and most productive gear in Massachusetts, followed in descending order by dredges, tongs, and hoes. Bull rakes, basket rakes, and tongs are used from small boats in shallow bays and coves along the entire Cape, on the shores of Buzzards Bay, Nantucket, Martha's Vineyard, and the Elizabeth Islands.

Dredges are restricted by law to deeper offshore waters, while hoes are used only on intertidal flats which are exposed at low tide. The Fall River or Nantucket dredge is typically a New England gear, and is rarely found in the Middle or South Atlantic States. The average dredge weighs about 450 pounds. The width of the blade, which varies from slightly less than two feet to about four feet, is usually expressed in terms of the number of teeth. Small dredges carry as few as 9 teeth, while large ones may have up to 24. The length and angle of teeth, as well as the amount of ballast attached to the dredge frame, depend largely on the nature of the bottom. The bag of the dredge is composed of iron rings and connecting links, the diameter and length of which are determined by local minimum-size limits and by the nature of the bottom.

GENERAL CONDITIONS OF THE FISHERY AND PROBLEMS: Individual townships assume the responsibility for their shellfish resources. The issuance of licenses and grants for holding grounds, establishment of closed areas or seasons, and regulations of the daily catch limit for hand or power fishing are all under the control of the town selectmen or board of aldermen. State health officials work with the towns in prohibiting fishing in contaminated waters, and State conservation personnel assist in transplanting and re-seeding projects.

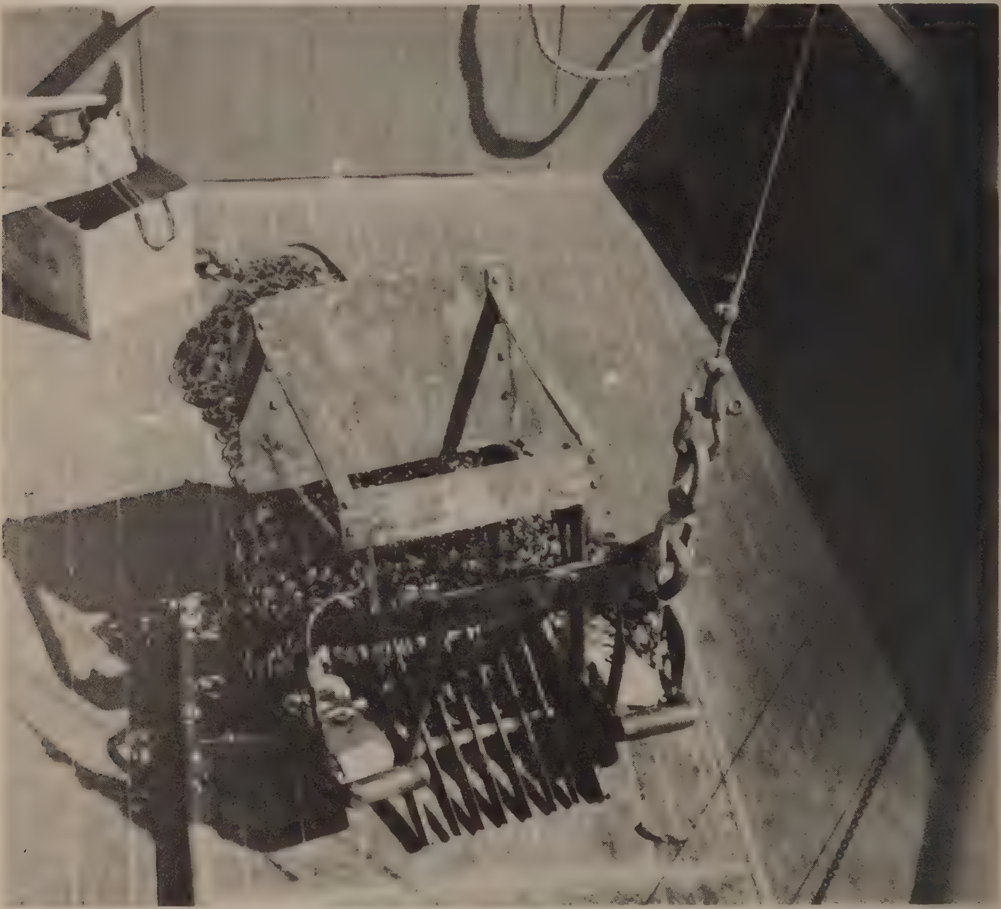

FIG. 4 - "FALL RIVER" DREDGES OPERATED BY POWER BOATS ARE USED PRINCIPALLY IN MASSACHUSETTS AND RHODE ISLAND AND ON LEASED GROUNDS IN NEW YORK.

Nearly all of the dealers and town shellfish warden reported evidence of depletion. In nearly every instance, failure of setting combined with overfishing were believed the cause. This apparent depletion is noticeable, particularly in the scarcity of "necks," the highest-priced, and consequently most heavily fished size. Statistical records for the period from 1931-48 show periodic fluctuations in the catch, which may indicate alternate periods of successful and unsuccessful spawning. The reported decline may be, therefore, only a temporary condition, caused (as suggested by the men interviewed) by heavy cropping of recent year classes without recruitment. Nearly all of the clam-producing areas in the State are said to be good natural seeding areas, but none is characterized by successful sets every year.

With the exception of one or two areas in which pollution has reduced the size of the grounds, and thereby increased the fishing pressure on other areas, fishermen and dealers believe that the stocks of clams can still support the same number of men.

Marketing is no problem in Massachusetts. Demand reportedly exceeds supply, particularly for little necks, and some dealers have found it necessary to buy from Rhode Island to fill their orders. Canneries and restaurants provide a good outlet for chowder clams, and summer residents supplement the already heavy demand for the smaller little necks and cherrystones.

Records of the catch for each town are compiled annually, and the daily limits are adjusted when necessary to prevent overexploitation. Transplanting projects are considered very important in maintaining the productivity of the clam beds.

Fluctuations in the total catch for the State have been of about the same amplitude over a period of years. The peaks of 1931, 1938-39, and 1945-46 were surprisingly similar, and the low years of 1935-37, 1943, and 1948 were also nearly equal.

It appears that the fishery in its present condition is limited in potential production, and is being exploited to about its fullest extent.

RHODE ISLAND

LOCATION OF THE FISHERY: Hard clams are restricted to the upper two-thirds of Narragansett Bay, and are rarely found in commercial abundance beyond a depth of 25 feet. The most productive beds occur in the more shallow inshore areas.

GEAR AND METHODS: Bull rakes and tongs, similar to those employed in Massachusetts, are the most productive gears in Rhode Island.

Dredging is restricted to the lower half of the Sakonnet River, and is permitted only from December 1 to March 31. The Fall River dredge, already described for Massachusetts, is generally used, but in the last few years it has been supplanted in some areas by a hydraulic-jet dredge. This gear employs high-pressure streams of water directed into the bottom just in front of the dredge blade, and greatly increases the efficiency of dredging in firm, sandy bottom.

GENERAL CONDITION OF THE FISHERY AND PROBLEMS: No serious problems of depletion or marketing were reported by any of the persons interviewed in Rhode Island. Consistently favorable comments were obtained with respect to the present supply, the success and frequency of setting in the past several years, and the number of fishermen who find clam fishing profitable.

The present intensity of the fishery by hand methods and the possible expansion of power dredging have raised the question of the effect of increased fishing pressure on the clam population. This basic problem faces the conservation department of every state having a hard-clam fishery. Each must know how many clams can be harvested each year without causing depletion. Greenwich Bay, which supports 30 to 50 tongers and rakers, was chosen recently by the Fish and Wildlife Service for productivity studies to determine the number of bushels of clams which can safely be removed each year. Records of commercial production are balanced against information concerning growth rate, setting, predators, and natural mortality. A clam census is taken once each year to determine what the fishery is doing to the population level. The results of these studies should help the states to determine whether their fishery is too intensive or if it can safely be expanded.

Considerable concern was expressed by all dealers interviewed regarding the capture and out-of-state shipment of sub-legal clams. This business has expanded greatly during the last several years, and dealers believe that severe depletion of the clam resources of the State will result unless this practice is curtailed.

Several men interviewed (all of whom are dredge operators or who depend on the dredge fishery for their supplies of clams) mentioned another problem. Legal dredging in Rhode Island is restricted to a comparatively small area. This area has been open to dredging since 1927, and has been depleted until at present it supports only 5 boats instead of the former fleet of nearly 40. Even when equipped with "jet dredges," which can harvest clams from beds which are too hard to be fished with the regular dredges, the fishermen report that it is almost impossible for a boat to fish profitably in the dredging area. They believe firmly that unless additional grounds are opened to them, it is doubtful whether the dredge fishery can survive another season.

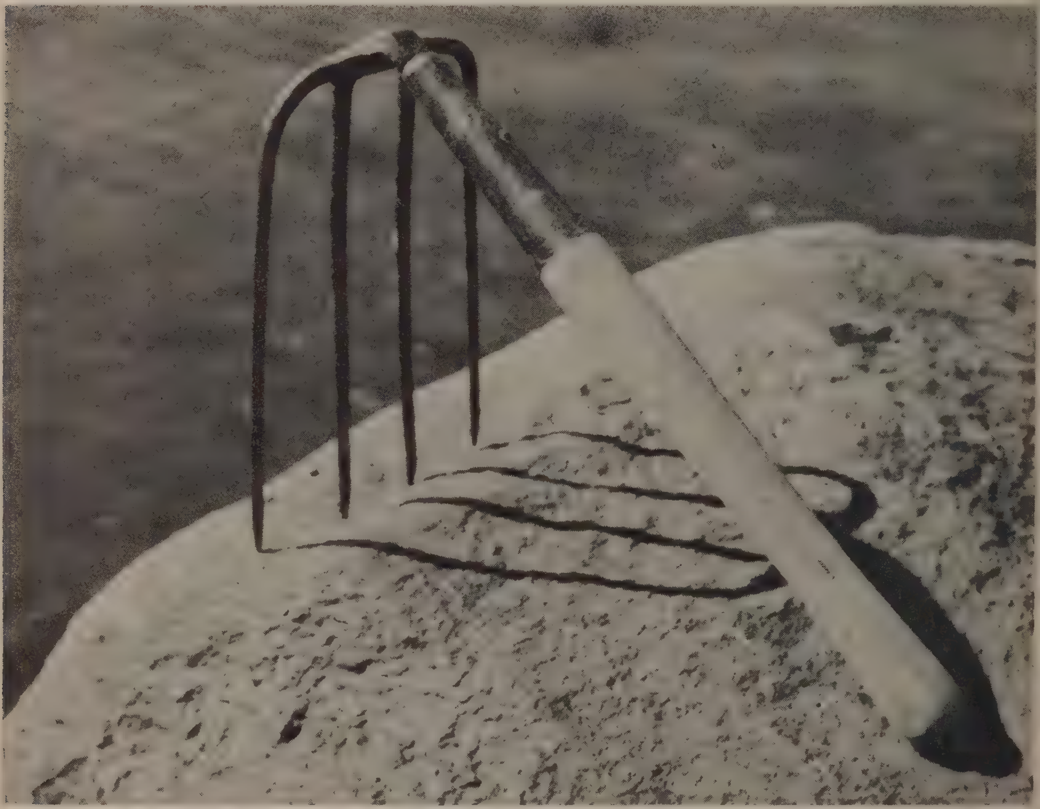

FIG. 5 - THE CLAM HOE IS USED PRINCIPALLY IN NEW ENGLAND.

Pollution is a problem in some areas of Narragansett Bay, according to dealers but is not serious enough to prevent the Rhode Island clam fishery from reaching high levels of production. Fishermen report no evidence that predators are a serious threat to any of the Rhode Island clam beds. Unless setting is unsuccessful for several years, or over-intensive fishing for sub-legal sizes is permitted, there is apparently little danger of depletion.

CONNECTICUT

The coast line of Connecticut, slightly over one hundred miles long, has practically no sheltered water. There are no barrier beaches to break the force of ocean waves, and practically no bays or coves typical of the productive areas in Massachusetts, Rhode Island, New York, and New Jersey.

The waters of Fairfield County are sheltered to a limited extent by Long Island, and together with the few small coves and inlets near New London and Mystic produce nearly the entire catch of hard clams in the state.

Tongs are the most numerous and most productive gear, and rakes rank second in catch. Power dredges are illegal on natural beds, but probably account for a considerable part of the catch of clams taken from privately-leased shellfish grounds.

Hard-clam fishing is of minor importance in Connecticut. The diggers do not depend on clams for their entire annual income, and work at this only when other fishing is unprofitable. Dealers stated there is no apparent depletion and report that hard clams never have been very abundant in this State.

Unpolluted waters are limited, and are occupied largely by privately-leased oyster grounds. These grounds yield small quantities of hard clams, but not enough to support a fishery. During World War II, one fisherman located a small bed near Milford, leased the ground, and dredged it until it became unprofitable, at which time he dropped his lease.

Commercial oyster growers make no effort to cultivate clams on their grounds, but do market those taken in their oyster-dredging operations.

Nearby cities provide a ready outlet for Connecticut clams, and marketing is never a problem. Dealers requiring large quantities for restaurant or hotel contracts often find it necessary to buy from New York or Rhode Island, particularly during the summer when tourist trade increases the demand. Even the many roadside stands which open during the summer are dependent almost entirely on out-of-state clams to supply their needs.

Highly efficient and practical methods of seeding, transplanting, and harvesting oysters have been developed by Connecticut oyster growers, and it is possible that clam farming may also be attempted if practical techniques are developed. Some of the dealers who were interviewed expressed interest in clam farming, but felt that a sufficiently rich source of seed was not available. None of them could recall having seen a heavy set of clams in Connecticut waters.

NEW YORK

LOCATION OF THE FISHERY: The hard-clam fishery of New York is concentrated principally on the southern shore of Long Island in the sheltered bays, protected by the barrier of beaches extending from the mainland nearly to the eastern tip of the island.

There is considerable production on the northern shore of Long Island, but the clam-producing areas are limited to a few relatively small bays and harbors, some of which are polluted.

Three areas of productivity may be delimited on Long Island. These are, in descending rank, as follows:

1. Great South Bay--in which the western portion is more productive than the eastern portion.

2. Port Jefferson to Cold Spring Harbor on the northern shore.

3. Greenport to Peconic Bay.

GEAR AND METHODS: The following types of gear are employed and have been arranged in descending order of their production.

1. Tongs are employed on hard bottoms to a depth of about 20 feet.

2. Bull rakes and scratch rakes are used in New York. The former have already been described in the section dealing with gear and methods. Scratch rakes are shorthandled, used by fishermen who wade in shallow areas and tread for clams with bare feet or search for siphon holes in shallow water or on exposed beds.

3. Dredges are essentially the same as those described for New England, and may be used legally only on privately-leased grounds.

GENERAL CONDITIONS OF THE FISHERY AND PROBLEMS: The fishery is in excellent condition at present, production is high, and with the exception of Great South Bay duck-farm pollution, few problems were reported by the dealers and fishermen interviewed.

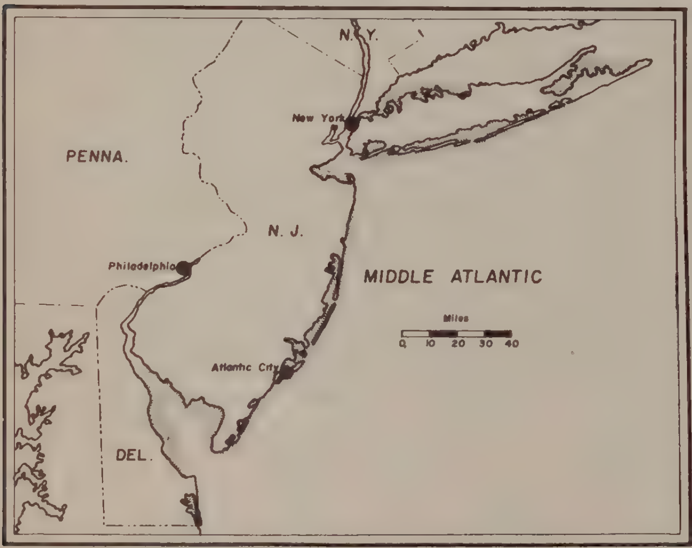

FIG. 6 - LOCATION OF HARD-CLAM FISHERY IN MIDDLE ATLANTIC STATES SHOWN BY STIPPLED AREAS.

Until about fifteen years ago Shinnecock and Great South Bays were the most consistent clam-producing areas, but in more recent years clams have been found in nearly every bay or cove on both north and south shores.

The opening of the intra-coastal waterway around 1930-31 with channels to harbors for the coastal towns (Babylon, Bay Shore, Lindenhurst, etc.) was followed by greatly increased clam production. It is the general opinion of local dealers and watermen that increased salinity tripled the clam-producing area of Great South Bay. Eel grass began to disappear about 1931, and also is believed to have increased the clam-producing bottom by permitting good circulation of previously choked shallow flats.

Fishermen report sets are not regular, but frequent enough to maintain a good constant supply of clams. The most recent heavy set appearing in the fishery occurred in 1941. This set was good along both north and south shores, with the result that the north shores are at present more productive than ever.

Dealers in the eastern part of Long Island (Orient Harbor, Peconic Bay, Shinnecock Bay, and Moriches Bay) reported depletion of clam stocks and believed overfishing and failure of setting to be the principal causes. This apparent depletion is probably not as serious as the dealers reported. Two influences are present which can produce a reduction in yield without actual depletion. First, fewer men are employed in the fishery, resulting in lower production. The second influence is the inability of the individual dealer to compete as effectively as in the past for the limited supply of clams. The consistently higher prices which have prevailed for the past several years and the proximity of the New York market have lured many more small buyers into the business. These small buyers can operate with low overhead, and can therefore pay a slightly higher price than the established companies.

Further west on Long Island, dealers reported the fishery to be in excellent condition. They did not recognize any depletion, and although some of them believed that there are fewer fishermen in the business, they felt this is due to lack of recruitment rather than a shortage of clams.

Dealers believe pollution is more serious than depletion in New York. State health authorities have closed a number of productive areas on Long Island because of sewage pollution. Some of these are closed all year; others are closed only during the summer months when the influx of tourists increases the sewage problem. The State conducts extensive transplanting projects to reclaim clams from areas closed because of pollution. The reclamation is mandatory and consists of supervised removal, sale, and replanting of the clams in approved waters. Usually the clams are sold at about one-half the current market price, but are abundant enough to make the work profitable to the fishermen.

Another type of pollution is becoming increasingly serious in southern Long Island, and in time may have very damaging effects. A number of duck farms on the shore of Moriches Bay discharge large quantities of duck excreta into the water. This material is said to increase the phosphate content of the water and when prevailing easterly winds during the summer carry this water into eastern Great South Bay, blooms of a Chlorella-like organism frequently occur. Unpublished results of studies conducted by biologists working for shellfish companies have reported that the organism becomes sufficiently abundant to clog the gills of clams and inhibit feeding, resulting in "poorness" and a reduced yield in shucking. This problem has not seriously affected the Great South Bay fishery, although canneries, buying for the greatest possible yield in shucked meats, will occasionally buy elsewhere when these clams are in poor condition. The restaurant and raw-bar trade for the smaller, higher-priced clams is unaffected. A complete biological and hydrographical survey of this problem was undertaken in 1949 through cooperative efforts of the State of New York, the Woods Hole Oceanographic Institution, and dealers in the affected area. Preliminary reports on this study are being prepared, and are expected to be released in the near future.

Marketing was not reported as a serious problem by any of the dealers interviewed on Long Island. The proximity of the New York market makes it the best outlet, and most Long Island clams are shipped there, where they may be sold and reshipped. Some, however, are shipped directly to western New York State, Connecticut, and to more distant markets in Maryland, Pennsylvania, and Ohio.

Tabular and graphic data already presented have shown New York ranks first in hard clam production, and it appears that the State's clam resources are in no immediate danger of overexploitation.

NEW JERSEY

LOCATION OF THE FISHERY: Hard clams are caught along almost the entire coast from Sandy Hook Bay to Cape May. Barrier beaches and islands shelter nearly all of the shore line, and clams occur abundantly in the harbors and bays behind these barriers.

According to some of the dealers interviewed, New Jersey's most productive clam grounds extend from the southern part of Barnegat Bay to Cape May, and Fish and Wildlife Service records of the catch by counties for the period 1931-47 support this idea. The best areas are Little Egg Harbor and Great Bay.

GEAR AND METHODS: With the exception of local modifications of dredges and rakes, the gear employed is similar to that used in New York, and is listed below in descending order of production:

1. Tongs.

2. Rakes include bull rakes; jig rakes, which are simply bull

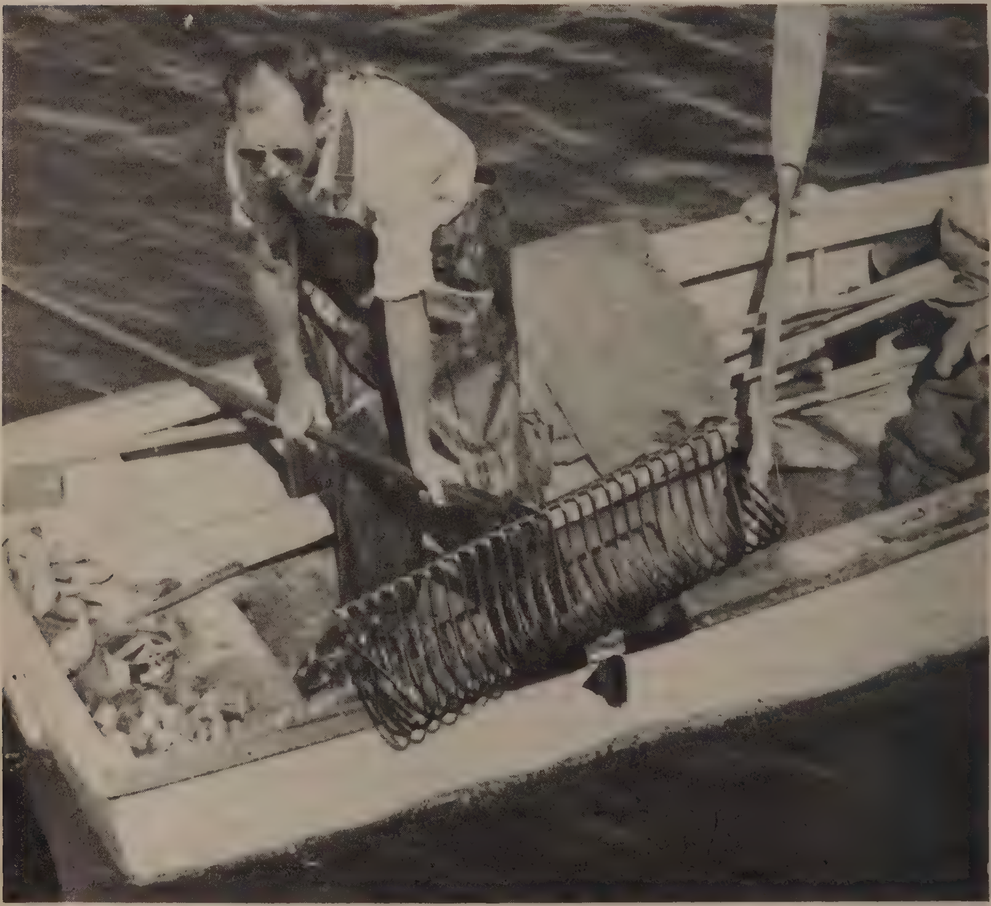

FIG. 7 - BULL RAKES ARE EQUIPPED WITH SECTIONAL STALES OR HANDLES FOR FISHING IN WATER 20 TO 25 FEET DEEP.

rakes with sectional handles composed of 5-foot lengths of steel pipe; and short-handled rakes used in shallow areas.

3. Dredges of two types are used. One similar to that described for the Massachusetts fishery may legally be employed only on private grounds. The other, a gang-rig, consisting of three or four short-handled bull rakes fastened to towing lines, is operated from sail boats in public waters.

GENERAL CONDITION OF THE FISHERY AND PROBLEMS: Fish and Wildlife Service catch records for New Jersey indicate no depletion in the State's hard-clam resources. In fact, 1948 was considerably above the average annual production for all years since 1931. Dealers, however, reported a decrease in the supply of clams, especially those of smaller size, and little evidence of a successful recent set. All of the men interviewed who believed depletion has occurred, felt that overfishing and failure of setting were the principal causes.

Some of the fishermen were more optimistic about the condition of the industry, and felt that if small clams are somewhat more scarce than in recent years, it is a temporary problem which has occurred periodically in the past. Successful sets are said to occur only occasionally, but support the fishery for several years. Temporary scarcity of small sizes may occur between the periods of successful setting, but this condition is not believed to be indicative of a permanent decline in the fishery.

Marketing presents only a minor problem in New Jersey. There is a constant demand for small clams to be served as "half-shells" or "steamers," particularly during the late summer when clambakes are most popular. The demand is so great for very small "steamers" in some localities that a considerable amount of undersized clams are taken, and in some areas this illegal fishing is considered a contributing factor in the apparent depletion. Canneries provide a lower-priced outlet for medium and large clams which are used in preparing chowder, minced, and canned clams.

The principal markets for New Jersey clams are in New York, Pennsylvania, and Ohio. Many dealers maintain leased beds on which they hold clams bought during periods of depressed prices on glutted summer markets. These men have found that bedded clams are subject to high mortality if held for more than one season unless planted more thinly than is desirable for easy recovery. Usually fishing is reduced during the winter, and demand exceeds the supply, so the bedded clams may be probitably sold later in the same year in which they were purchased.

Pollution is a problem in only a small portion of the clam-producing areas of New Jersey, and most of it occurs in the less productive northern part of the coast. With the exception of areas near Atlantic City and Wildwood which are closed during the summer when the population is greatly increased by vacationists, the shores of the most productive bays and harbors are so sparsely populated that sewage pollution is no problem.

Apart from the reports of dealers cited previously, there is little evidence of depletion of New Jersey clam resources. Production has been at a very high level for the past several years, and unless increased market demands intensify the fishing effort, it seems unlikely that depletion from overdigging will occur.

DELAWARE

The clam-fishing grounds of Delaware are very limited, and the production, when compared to New York and New Jersey, is so small as to be almost insignificant. The western shore of Delaware Bay in the vicinity of Little Creek support a dredge fishery which accounts for the major part of the production, and the sheltered waters of Rehoboth Bay and Indian River Bay maintain a very small tonging fishery.

Dredges are the only gear used in the Delaware Bay fishery, since the water is too rough for the small boats used by tong-and-rake fishermen. The dredges ar simply modified oyster dredges equipped with teeth from 6 to 9 inches in length.

The clam-dredging fishery, which accounts for almost the entire catch in Delaware, developed as a sideline of the oyster business of Delaware Bay. Boats operated in the Little Creek area dredge small quantities of clams from privately-leased oyster beds, but their largest catches are taken from adjacent natural grounds. Ordinarily, clam fishing stops at the end of the oyster season because the price of clams is lowest during the summer, and they must be sold promptly to avoid loss by spoilage. Good market conditions in 1949 and 1950, however, have encouraged some of the dredgers to continue operations during the summer. No effort has been made to maintain holding beds, since dredging is typically a winter fishery, and mortality is high in winter plantings, according to dealers.

Almost all of the dredged clams are large enough to be used by canneries, since the $2\frac{1}{2}$-inch rings used in the dredge pockets allow most small clams to escap

Clam production in Delaware Bay has been increasing steadily for about three years. Dealers interviewed reported 1950 catches at an all-time high level, and believed the last similar peak of production occurred in about 1932.

The Indian River and Rehoboth Bay areas were described by local shellfish dealers as unproductive when compared with Chincoteague Bay, which lies a few mil south. Only about seven men in the vicinity of Oak Orchard dig clams commerciall and the largest individual shipper in the area handles only about 2,500-5,000 cla per week. A State law limits a fisherman's daily catch in the Indian River to 1,000 clams, but the scarcity of clams makes it difficult to reach this limit.

There seems to be no problem of marketing the available supply, and no evidence of depletion. The supply is limited to a small area, and is simply not grea enough to maintain a large fishery.

Pollution is not serious with respect to the Delaware clam fishery, since th limited areas in which fishing is profitable are free from pollution.

It appears that the fishery of Delaware is being exploited to nearly its ful est extent. Continuation of dredging through the summer may increase production, but if the clams are cyclic in abundance, the particular size groups in which the dredges are most effective will probably be diminished until another successful period of recruitment occurs.

MARYLAND

LOCATION OF THE FISHERY: Although Pocomoke Sound, located in the southeaste part of Chesapeake Bay yields small quantities of clams, nearly the entire catch comes from the protected bays on what is locally called the sea side of Maryland. Chincoteague, Sinepuxent, Assawoman, and Isle of Wight Bays form a continuous bod of water along the entire east coast. The whole area is very shallow, rarely exceeding 12 feet in depth at high water, and the bottom is largely composed of soft, sandy mud, with scattered areas of shell formed by natural oyster beds.

GEAR AND METHODS: With the exception of small quantities taken by dredges working on the lower Chesapeake oyster beds, tongs and rakes account for the entire catch of clams in Maryland waters. Rakes are used principally in the summer when fishermen can wade and tread clams, or locate them by "signing" at low tides when the bottom conditions are right. This method is used by skilled fishermen who can recognize the "sign," which may be a mound, depression, or any hole in the bottom indicating the position of the clam. Tongs, which produce about the same as rakes, are used in both summer and winter in deeper water, and are particularly effective on the natural oyster beds where clams are abundant.

GENERAL CONDITION OF THE FISHERY AND PROBLEMS: Catch records for the period from 1931-48 show a steady increase in production, with only occasional minor regressions. Although somewhat less than 1947, the catch for 1948 is still well above any other preceding year.

Depletion was considered a major problem only in the Chesapeake Bay clam fishery. Dealers in Crisfield reported that formerly productive beds in Pocomoke Sound have become so depleted during the last fifteen years that they now produce virtually no clams.

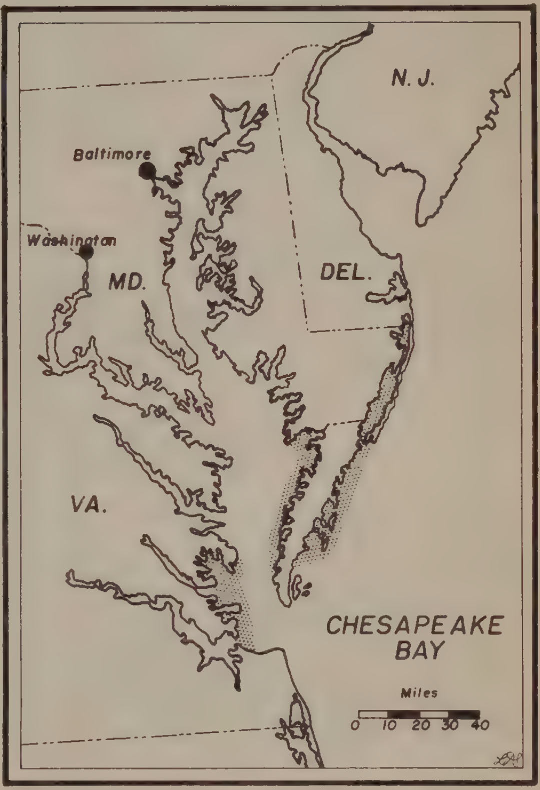

FIG. 8 - LOCATION OF HARD-CLAM FISHERY IN CHESAPEAKE BAY STATES--STIPPLED AREAS.

Members of the Maryland shellfish industry who were interviewed almost universally agreed that marketing is the major barrier confronting the Maryland clam fishery. The greater volume of production in New England offers serious competition to a year-round market. Nearly all Maryland dealers depend largely on "bedding"--clams bought at low prices during the summer and on the re-sale of the clams during the winter. In normally severe winters, the New England fishery is considerably restricted, and "bedding" is quite profitable. A number of dealers stated that they have bought and held clams from New York, New Jersey, Rhode Island, and North Carolina to augment their local supply. Mild winters during the last few years have made this practice risky, and several dealers reported that the poor winter market had forced them to reduce or abandon "bedding" operations.

The outlet for Maryland clams is almost entirely out-of-state. Regular markets are found in New York, Pennsylvania, Ohio, Florida, and even Texas. The peaks of demand occur during late summer for small clams used in clambakes, and during the winter for large chowder clams.

Two firms within the State produce canned chowder, and very recently another company has begun freezing clams with satisfactory results.

Pollution presents no problem to the Maryland clam fishery since most of the clam-producing area of the Eastern shore is sparsely populated.

The steady increase in production, despite a reported reduction in fishing effort, indicates that the industry is growing even though marketing problems are severe. These problems may be overcome with the development of efficient techniques of freezing and processing. Long-distance shipment at minimum cost could provide new outlets, and offer better competition to the New England clam fisheries.

VIRGINIA

LOCATION OF THE FISHERY: Virginia's hard-clam fishery is centered along the eastern peninsula. The sheltered bays from Cape Charles to Chincoteague Bay are most productive, but considerable quantities are also taken from the lower Chesapeake Bay.

The western shore of Chesapeake Bay from Mobjack Bay to Cape Henry is also quite productive. Broad shallow flats cover much of the area, and small coves and creeks provide excellent holding grounds.

GEAR AND METHODS: Tongs and rakes are the most productive gears, and dredges account for only a small part of the catch. Hand tongs are most numerous, but in some areas in Chesapeake Bay the use of power-operated patent tongs is permitted, and in those areas, this gear is very important. Patent tongs are exactly the same in design as hand tongs, except that the shafts are shorter, and made of iro instead of wood, and that the head or basket is much larger. Wire ropes replace the shafts, but the tongs are worked into the bottom by the same scissor-like action. This gear was originally developed for use in oyster fishing, but has proved very efficient in catching hard clams.

The type of hand-operated gear varies with the season. In winter, tongs are used almost exclusively, while in the summer rakes are used very extensively by fishermen who take clams by treading and "signing."

No dredges are licensed for clam fishing in Virginia, and the catches listed are taken incidentally in dredging for oysters and crabs. Clams are seldom dredge from privately-leased holding grounds, principally because these grounds are ofte in very shallow areas.

GENERAL CONDITION OF THE FISHERY AND PROBLEMS: Although the annual catch during the period from 1944-48 was not as high as in previous years since 1931, the lower production should not be interpreted as evidence of a serious decline or depletion. Only one of the many dealers interviewed believed that the stocks of clams were reduced. In all other instances, overproduction and marketing were considered the most serious problems.

The planting of clams on privately-leased grounds is one of the most importa parts of the industry. It is very difficult for Virginia dealers to compete profitably with the great production from the New England and Middle Atlantic States. There is a steady year-round demand, but prices are depressed during the summer when clams are plentiful and Virginia dealers consider winter trade most profitable. In severe winters when New England clam fishing is restricted, Virginia dealers can profitably sell clams bought during the previous summer and held on leased beds. Unusually mild winters during the past few years have made holding clams unprofitable. A number of men reported serious losses from holding clams for two years. The heavy losses from holding beds reported by some dealers may have been due to overcrowding, and the development of better farming techniques might be of great value during periods when depressed prices necessitate long holding periods.

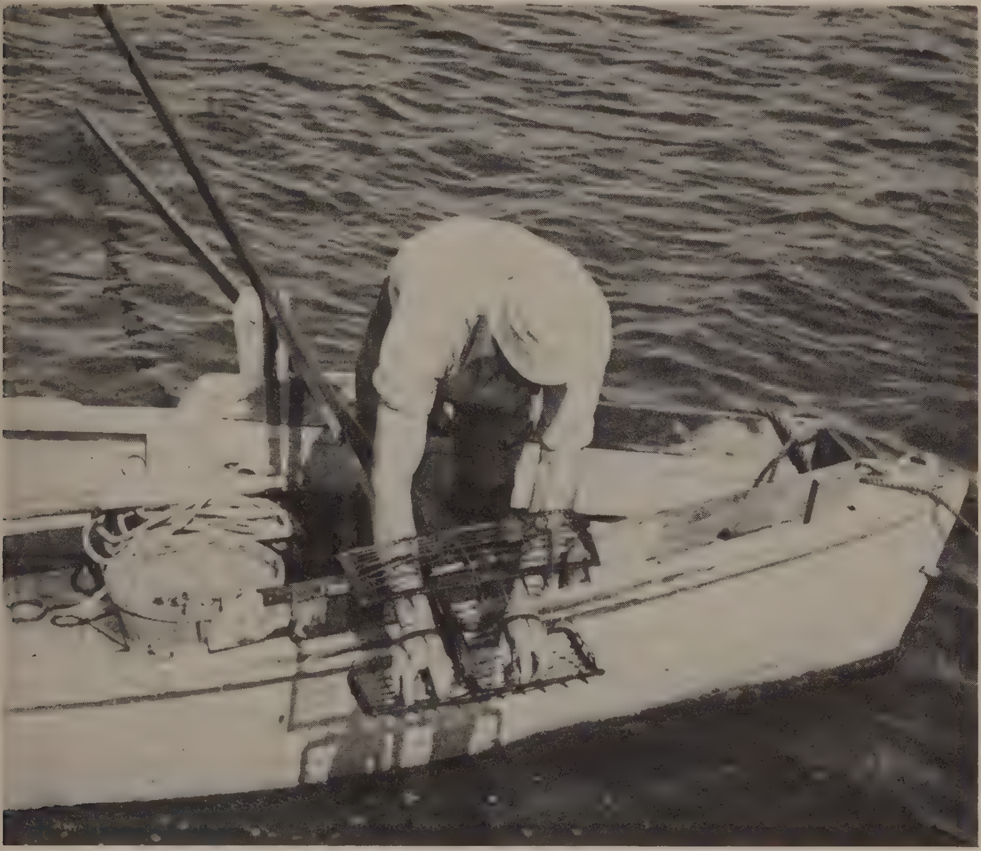

FIG. 9 - TONGS ACCOUNT FOR OVER 60 PERCENT OF THE ANNUAL HARD-CLAM CATCH.

Local markets consume some of the catch, but Pennsylvania, New York, and Ohio, and even Florida, provide the principal outlets. There is at present no large-scale effort being made to process clams, and practically all are sold in the shell. There is only a very limited local market for shucked clams, principally for restaurant and retail trade.

Pollution occurs only in a comparatively small area around Norfolk and is not a serious problem. State health laws permit the sale of clams from contaminated water, if they are transplanted to a pure area and held for one month.

Predation is usually not a serious problem, but occasionally skates invade the holding beds in the Chincoteague Bay area. One man reported the loss of 600 bushels of small clams in two nights during 1948, and said it was necessary to fence his holding beds to exclude these predators. Fortunately, skates do not come into the Bay every year, and the 1948 invasion was the first serious attack to occur in five years.

NORTH CAROLINA

Hard clams are found in nearly all of the sheltered coastal waters of North Carolina, but the commercial fishery is centered principally in Carteret and New Hanover counties. Statistics of the Service reveal that smaller quantities are also caught in Brunswick, Dare, Hyde, Onslow, and Pender counties.

Rakes, used by fishermen wading in shallow water or on beds exposed at low tide, account for almost the entire hard-clam catch. Tongs are used, but except in Carteret County, these are so few that their contribution to the catch is negligible. Dredging began about December 1949 in Carteret County and now accounts for almost the entire catch of this county.

The opinion of dealers and biologists interviewed in North Carolina was that the principal problem facing the hard-clam fishery is market development, although some concern was expressed over the effect of the new dredge fishery.

Clams are abundant, but the distance to markets makes transportation very costly. Most of the clam diggers work only part time, and turn to other fisheries whenever it appears more profitable.

It is possible for southern clam diggers to work during winter months when weather curtails the New England fishery, and North Carolina men find the winter season profitable. Maryland and Virginia have similar advantages of weather, however, with a further advantage of being closer to the northern markets.

"Bedding" of clams bought cheaply during the summer is a common practice, but is considered risky, particularly during the mild winters of the past several years In "bedding"," as in the fishery for native clams, Virginia and Maryland offer sharp competition.

Contracts with northern canneries for large chowder clams provide one good outlet, and the technique of freezing shucked meats and liquor separately had reduced transportation costs by increasing the pay load. Only a few dealers ship directly to northern markets. Most clams are sold in the shell through dealers in Virginia and Maryland.

Pollution and predation are of no importance to the North Carolina fishery. Fishermen and dealers believe the supply of clams greatly exceeds the demand at present. It seems improbable that the resource will be fully exploited unless the market is expanded to offer profitable full-time employment to fishermen or unless a more intensive dredge fishery develops.

SOUTH CAROLINA

Catch statistics indicate that the hard-clam fishery is concentrated in Horry and Georgetown Counties, but fishermen insist that Charleston and Beaufort Countie also have extensive clam beds. A sea-food producer of Beaufort reported that the hurricane of August 1940 exposed a three-quarter mile bed at Trenchard's Inlet "on which clams were so thick that there was not a hand's breadth between them."

Rakes account for most of the catch, a considerable part of which is dug on exposed flats at low tide. Although dredges used in the oyster fishery also catch a few clams, the catch is insignificantly small. Dredge production is limited further by a State law which prohibits dredging for clams in less than 12 feet of water.

Marketing is apparently the greatest problem in the hard-clam fishery of South Carolina. All of the dealers and conservationists interviewed agreed that hard clams offer an almost unexploited source of wealth, but the problem of finding a profitable outlet has retarded the development of the fishery. Only during

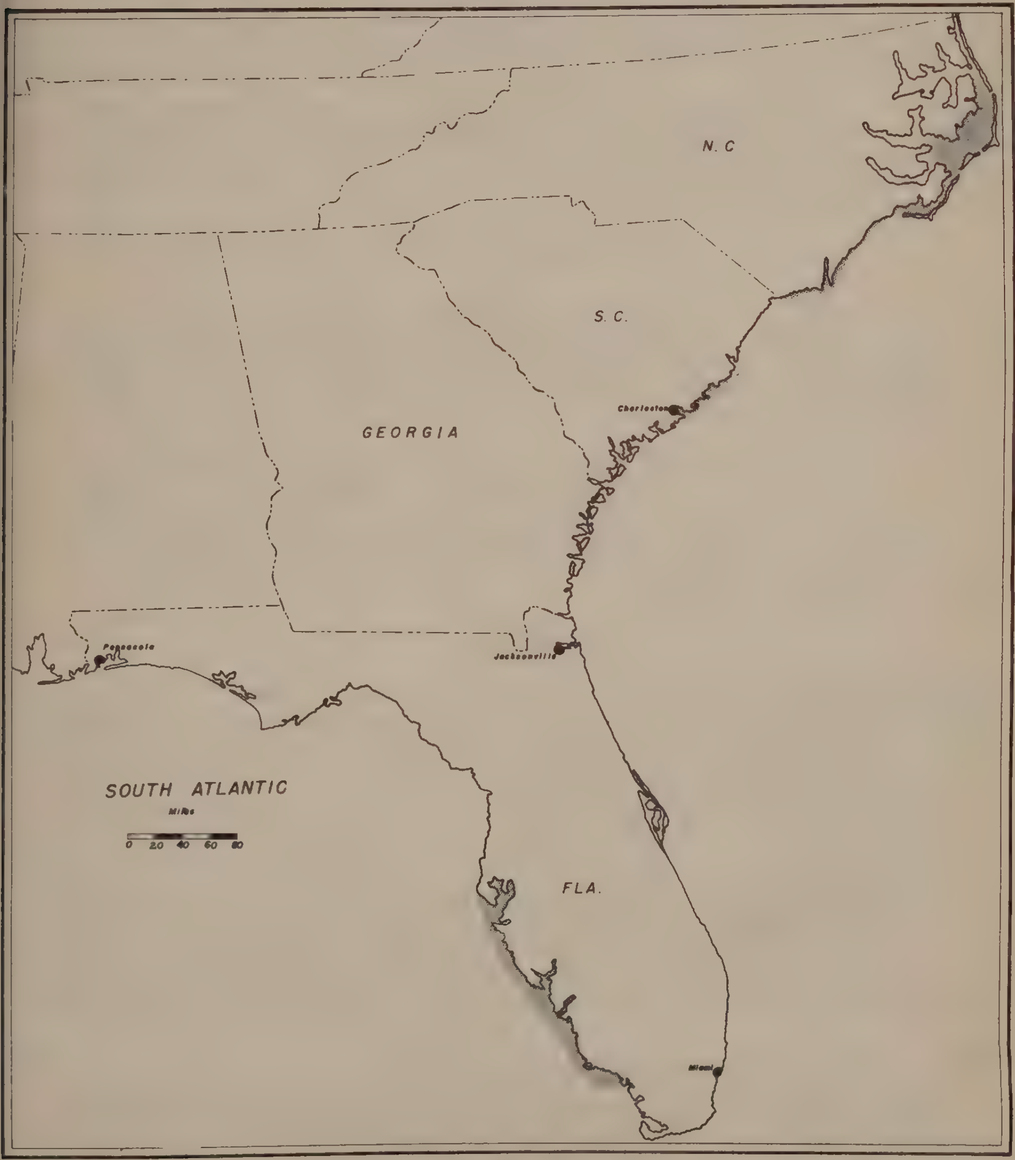
N. C
S. C.
Charleston
GEORGIA
Pensacola
Jacksonville
SOUTH ATLANTIC
Miles
0 20 40 60 80
FLA.
Miami

FIG. 10 - LOCATION OF HARD-CLAM FISHERY IN THE SOUTH ATLANTIC STATES SHOWN BY STIPPLED AREAS.

severe winters, when New England waters are inaccessible, can the Southern clams be dug and marketed at a price high enough to defray the expenses of packing and shipping to northern markets.

The oyster business is of much more importance, and extensive individually-leased areas are devoted to oyster farming. Holders of these leases are not greatly concerned with the development of a clam fishery, and at present there is little interest in clam farming. Clams occur on the leased oyster beds but are more abundant on public grounds.

South Carolina has 11 laws relative to clams some of which inhibit the development of an industry. One law specifies a closed season between May 1st and August 1st, which prevents marketing of clams during the period of peak demand from the raw-bar and clam-bake trade. Another law prohibits the out-of-state shipment of clams in the shell. This second law prevents shell-stock shipments to Northern canneries which use large quantities of clams for chowder or minced clam products. Local consumption is small, and unless an out-of-state outlet is found and a profitable method of shipping developed (perhaps as a frozen product), the industry shows little promise of developing.

GEORGIA

There is no commercial clam fishery in Georgia. Clams are found in most of the intra-coastal waters, but they are reported taken only for home consumption, and are believed not to be sufficiently abundant to support a fishery. The Service's records show no clam catch since 1932, when a total of 600 pounds was taken commercially.

There is virtually no local demand, and the distance from northern markets presents a serious barrier to the development of a fishery.

The introduction of efficient freezing techniques might be of value in developing a market, but at present there is little evidence that a fishery for hard clams can be built up in Georgia.

FLORIDA

LOCATION OF THE FISHERY: Clams are found along both coasts of Florida, but the greatest concentrations are on the west coast from Ten Thousand Islands to Tampa Bay. The beds in this area are reported to extend from Shark Point to Coon Key Light, a distance of about thirty-five miles. The inner edge is about one-eighth mile from shore; the outer edge about five miles. The total area of the beds is at least 150 square miles. The shore line slopes very gradually, and the depth 4 to 5 miles offshore is less than 12 feet in many places.

GEAR AND METHODS: Rakes, hoes, and grabs are the only types of hand-operated gear, and are few in number. Reliable records of the number of units of these gear are not available, but on the basis of interviews it may be stated that the number of men is small, compared to the numbers employed in other fisheries. Clam digging is usually a part-time occupation pursued when other fishing is unprofitable.

A conveyor-belt dredge was introduced into the Ten Thousand Islands clam fishery about 1913, and this type of dredge was used, with some modification and improvement, until 1947 when operations became unprofitable. All clams taken by the dredge were shucked and used for canned chowder, minced clams, and clam juice.

The dredge was essentially a large wooden scow, about 30 by 80 feet, with a rectangular opening in the bottom through which the dredge belt operated. Clams were washed from the bottom by high pressure jets of water, and brought to the surface by a conveyor belt. The earlier models of this dredge were self-propelled. An anchor was set and the dredge was allowed to drift or was towed to the end of the cable--a distance of about 1,000 feet. The dredge then hauled itself back to the anchor by means of a winch. The scoop of the dredge was about $3\frac{1}{2}$ feet in width, and a single set could therefore cover about 3,500 square feet. It was reported that the dredge operated 24 hours per day and could make about eight sets.

The most recent modification of this device is smaller in size, measuring 16 by 40 feet, and can operate in shallow water. It dredges a 24-inch swath, and may either be operated on an anchor cable, or towed by a power boat. Facilities are also provided for shucking and refrigeration, thereby minimizing the expense for shore installations needed to pack the clams.

The regular Fall River dredge used in the New England fishery has been tried in Florida, but although good catches were reported, it has never been used commercially.

GENERAL CONDITION OF THE FISHERY AND PROBLEMS: The status and potential production of the Ten Thousand Islands clam beds were reported in 1920, 1938, and 1943.

The first report, prepared by W. C. Schroeder of the U. S. Bureau of Fisheries, emphasized the great abundance of clams. The second report was by J. R. Kelly of the Florida State Board of Conservation who attempted to determine whether dredging operations were damaging or destroying the clam beds. This report contained affidavits obtained from a number of local watermen who claimed that serious depletion had occurred in the years the dredge has been operating. Overfishing, breaking of shells, smothering, removal of grass, and destruction of the habitat were cited as the principal damaging effects of the dredge.

In 1943, C. H. Chilton, a fishery marketing specialist for the U. S. Fish and Wildlife Service, visited the area and estimated the potential production of the fishery to be almost unlimited. He reported an estimated abundance of one bushel of clams per six square yards dredged.

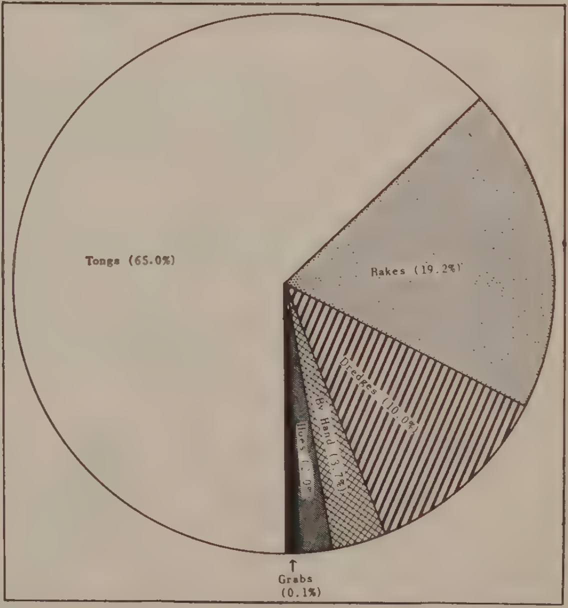

FIG. 11 - GEAR USED IN HARD-CLAM FISHERY MAINE TO FLORIDA SHOWN IN PERCENTAGE OF AVERAGE CATCH 1944-48.

The contradictory nature of these reports makes analysis of the available catch records for the area somewhat difficult. Service statistics are available by county and gear for only seven years between 1931 and 1947, but they do show a somewhat smaller catch for the Ten Thousand Islands area in 1947 than in any preceding year except 1934.

The men interviewed during the 1950 survey (upon which this report is largely based) felt that serious depletion had occurred, but that it was the result of an unusual natural mortality, and not the result of dredging.

One fisherman sampled the area with a Fall River dredge during 1948 and found clams sufficiently abundant to build another conveyor-belt dredge. In November 1949, he found that almost the entire population of clams had died. In eight days of dredging from Coon Key to Wood River, he found only eight live clams the remainder of his catch consisted of empty shells. Areas untouched by previous dredging yielded only dead clams.

The annual catch of the dredge from 1943 to 1946 was 30,000, 50,000, 78,000, and 25,000 bushels. In the year 1947, clams were so scarce that operations were halted. It is very difficult to trace and evaluate the trends of the Ten Thousand Islands fishery. Although intensive dredging may have contributed to a reduction in the stocks of clams, the fishermen we interviewed believed that a destructive natural phenomenon also contributed to the depletion.

At present there is no fishery reported in the area, and unless natural restoration rebuilds the population to its former abundance, it is doubtful whether any further effort will be made to develop a clam industry in the Ten Thousand Islands.

Interviews with dealers and conservation research personnel indicated that only limited stocks of clams have ever been found outside of the Ten Thousand Islands. Sufficient numbers for home consumption occur in many areas along both coasts, but commercial fisheries have been attempted in only a few places.

A small fishery existed at one time near Matanzas Inlet, and although a small stock of clams is still present, no effort is made toward commercial harvesting. Limited quantities occur in the inland waters from Edgewater through the Indian River, but there is no fishery. Clams are reportedly less abundant than before the opening of the intra-coastal waterway.

Charlotte Harbor and adjacent inshore waters near Englewood supported a small fishery, but during the last few years heavy mortalities have so depleted the stocks that fishing is no longer profitable.

Lower Tampa Bay provides a limited supply for local use, and a few large clams are taken near Clearwater. The upper limit of clam production is in the area of Cedar Key, where clams were reported to be fairly plentiful, but no attempt has been made to develop a fishery.

Florida dealers are faced with serious problems of marketing. With the exception of Miami, there is little or no demand except in the tourist season, and even then northern clams present a barrier to local marketing. Florida clams were reported by some dealers as being too large, too full of sand, and too difficult to ship without heavy mortality. These dealers find a more dependable supply and a better product from northern markets. One dealer reported buying 2 to 3 tons per week from northern markets during the November-March tourist season.

At present there is practically no hard-clam fishery in Florida. Restoration of the Ten Thousand Islands stocks might offer an opportunity for the development of a market for shucked frozen clam meats to be used by northern canneries, or perhaps for locally-canned clam products. It is doubtful, however, whether the industry could ever be developed sufficiently to offer effective competition to the big northern clam resources.

CONCLUSIONS

The hard-clam fishery of the Atlantic Coast presents no picture of general depletion such as that observed in the soft-clam fishery. Stocks of hard clams in most areas are adequate and fishermen and dealers are often worried more about demand than supply. Local exceptions to this statement are found--the most notable being the disappearance of the hard clams in the Ten Thousand Islands area in Florida. This area, once described as the greatest bed of hard clams in the country, now supports no commercial fishery. The cause of the disappearance of hard clams in Florida is a worthy subject for biological research.

The intensive tong-and-rake fishery in Rhode Island, together with the possibility of using more efficient power dredges, causes concern over the ability of the clam population to withstand increased fishing pressure. The Service's investigations in this State are designed to determine the productivity of Greenwich Bay in terms of the number of quahuags which can safely be removed each year. These studies present a unique opportunity to observe a commercial fishery before it has been dangerously depleted.

Pollution is a serious problem only in Massachusetts, Rhode Island, and New York. Both Massachusetts and New York salvage their clams from polluted waters by transplanting them to clean beds for a specified time before marketing. Effective disposal systems would reduce sewage pollution, enlarge the fishing area, and increase clam production.

Marketing was reported to be an important problem by all states from Maryland to Florida. These states must compete with the Middle Atlantic and New England States, but are handicapped by their distance from the centers of population.

Severe winter weather restricts the northern diggers, but southern fishermen seldom face this problem and usually find winter fishing profitable. Mild winters during recent years have permitted digging most of the year in New England and have thereby reduced sales from the South.

Another factor reducing the market for southern clams is the latter's lower yield of meats per bushel as compared with northern clams. Catch statistics indicate that hard clams from the New York-Maine area average about 11.5 pounds of meats per bushel; New Jersey and Delaware about 9.0 pounds; whereas Maryland-Florida clams averaged only 7.5 pounds per bushel. It is apparent from these figures that southern clams must be obtainable at a lower price to compete with those from northern waters.

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CERCARIA MYAE SP. NOV., A FORK–TAILED LARVA FROM THE MARINE BIVALVE, *MYA ARENARIA*

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Cercaria myae has been found in three of 910 specimens of the soft clam, *Mya arenaria,* collected in the vicinity of Newburyport, Mass. Two infections were found upon dissection and examination of 143 preserved specimens which had been collected in July, 1949. The remainder of the material consisted of many smaller collections of living specimens. These, too, were examined by dissection since the material was being utilized for several independent studies. The third infection was found in a May, 1951 collection and the description to follow is based mainly upon that source.

The cercariae are produced in motile, unpigmented sporocysts which occupy the interfollicular spaces of the gonad and the interlobular lymph spaces of the digestive gland; lesser numbers of sporocysts occur throughout the hemocoel. The gonad is the principal focus and severe atrophy of that diffuse organ is evident in sectioned material. There is histological evidence of partial to complete sterilization. In one of the earlier examples, the infection was so extensive that it is considered doubtful that similarly infected animals could survive abnormal conditions.

Cercariae were observed to emerge spontaneously from sporocysts which had been teased from the host tissues and placed in watch glasses containing sea water at room temperature. The sporocysts are typically clavate with thin walls and a birth pore in the apical end; they vary in length from 0.21 to 0.60 mm. The carcariae emerge either head or tail first after which they remain quiescent for several seconds. In swimming, the posterior portion of the body is bent ventrally in apposition to the anterior portion whereupon a vigorous lashing of the tail causes an inversion of the animal and a rising, random movement. The cercariae did not encyst and became moribund after about twelve hours. Owing to the limited amount of living material, exposure trials were not attempted.

The cercariae (Fig. 1) are small with elongate-ovoid bodies and a forked tail. The length of the body varies from 0.12 to 0.25 mm. in contracted and extended condition. The tail stem is short, about one third the length of the body, and slightly shorter than the furcae. The body is covered with minute spines less than 0.001 mm. long, and delicate setae occur on the posterior surfaces of the furcae. The oral sucker is relatively large, spherical to oval, and measures 0.039 to 0.052 mm. in diameter. It is followed almost immediately by a pharynx approximately half as large in diameter (0.020–0.025 mm.). A short esophagus quickly flares into large digestive ceca, the walls of which are composed of large polygonal cells. A small, deeply staining, spiral coil of supporting material maintains a constant lumen between the pharynx and esophagus; this structure is best seen in stained sections. The acetabulum is approximately as large as the oral sucker and varies from 0.040

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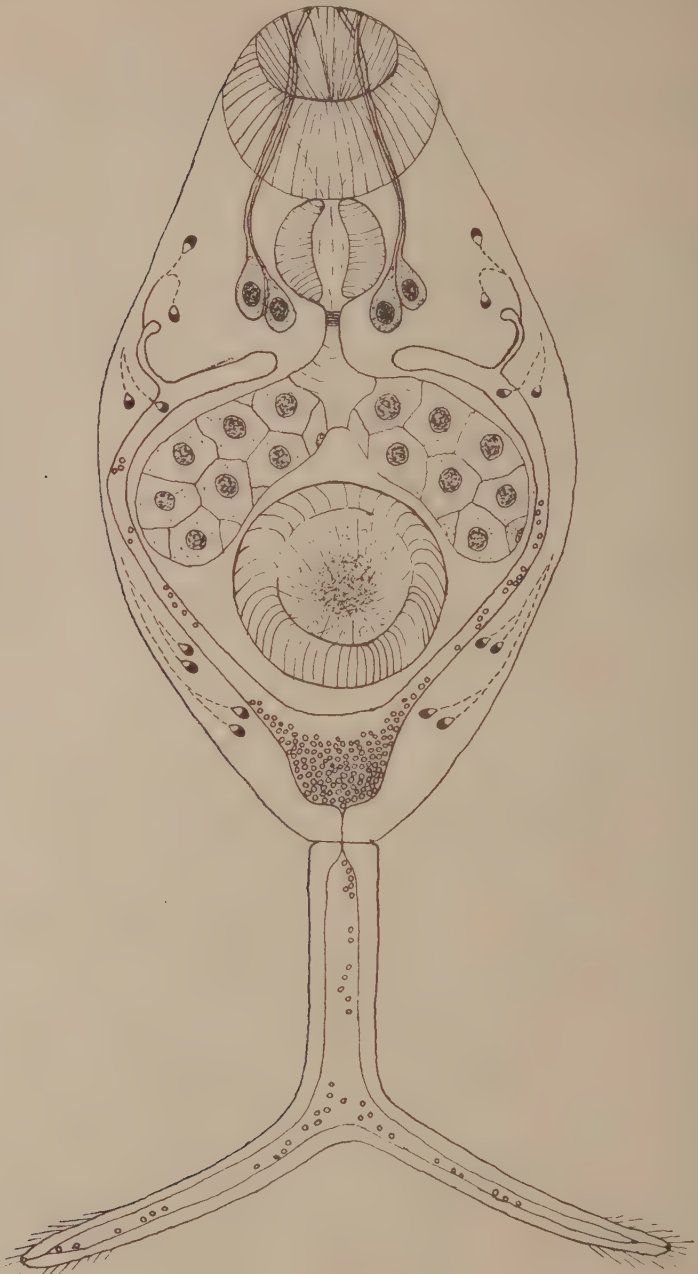

FIG. 1. *Cercaria myae,* ventral view.

to 0.046 mm. in diameter. Two pairs of penetration glands, with well defined ducts, are arranged in bilateral fashion near the posterior level of the pharynx. The ducts on either side are closely applied as they pass forward to the dorsal margin of the oral sucker, but diverge abruptly to open in four separate pores. The excretory vesicle is U-shaped with long arms that extend forward and bend mediad around the digestive ceca, terminating blindly near the penetration glands. Primary tubules arise near the ends of the arms. Sixteen flame cells have been located, but their connections could not be traced with certainty. The excretory vesicle opens into an enlarged caudal duct which traverses the tail stem, divides, and continues axially to the tips of the furcae.

Cercaria myae belongs in the group of Furcocercous Cercariae. Attempts to relate it to a distinct taxonomic group must await a knowledge of its post-larval form. It is interesting to note, however, the close morphological agreement between this form and another unclassified larva, *Cercaria discursata* Sinitsin, 1911, which develops in sporocysts in the gonad and liver of the marine bivalve *Abra* (= Syndosmya) *alba* of the Black Sea. In contrast to *C. discursata,* which does not swim and sheds its well-developed forked tail while still within the sporocyst, *C. myae* manifests a pronounced natatory ability. Apart from this difference and certain size discrepancies, comparison of the two suggests intrageneric relationship.

Stafford (1912) may be credited with the original observation of *C. myae* on the basis of a brief description which appears in a discussion of human illness and fatality, ascribed to shellfish poisoning. ". . . in a single case out of a very large number the whole abdomen of a clam (*M. arenaria*) was distended, soft, translucent, and pale yellowish-green in colour, while a puncture occasioned a copious flow of an aqueous fluid containing hundreds of *sporocysts,* most of which inclosed about 20 full-formed split-tailed *cercariae.* The body of one of these measured .138 × .082 mm. . . ." He hesitatingly suggested, without evidence, that this form could have been the basic cause of the shell-fish poisonings. It should be noted here that the fundamental cause of shellfish poisoning is believed to be associated with several species of dinoflagellates which appear in the planktonic food of molluscs. Needler (1949) presented data and reasons for regarding *Gonyaulax tamarensis* as the principal cause of shellfish toxicity in the Bay of Fundy area. Stafford's description of the cercaria, however, is suggestively diagnostic and in all probability refers to the species described here.

Allison (1943) experimentally traced the life cycle of *Leucochloridiomorpha constantiae* (Mueller, 1935), a brachylaemid trematode having natatory furcocercous cercariae which develop in an aquatic snail. Since all other known brachylaemid cercariae develop in terrestrial snails and have very abbreviated tails, he postulated that *L. constantiae* represents a surviving ancestor of the BRACHYLAEMIDAE. He suggested that *C. discursata* may possibly belong to the BRACHYLAEMIDAE and, in that case, would represent a form intermediate between the tailed and tailless cercariae of the family. If Allison is correct, *C. myae* could be tentatively referred to the same family. Further study of both species is highly desirable and may provide important information concerning the phylogeny of the BRACHYLAEMIDAE.

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JAPANESE MOTHERSHIP-TYPE TUNA-FISHING OPERATIONS IN THE WESTERN EQUATORIAL PACIFIC, JUNE-OCTOBER 1951

(Report on the Seventh, Eighth, and Ninth Expeditions)

By Wilvan G. Van Campen*

INTRODUCTION

A directive (issued in May 1950) by the Supreme Commander for the Allied Powers (SCAP) authorized the Japanese to send fishing vessels as far south as the Equator in the waters of the U. S. Trust Territory of the Pacific Islands, provided that such vessels were organized into fleets based on motherships or tenders capable of exercising control and supervision over them. In all, nine such fleets, varying widely in scale and scope, had fished for tuna in the waters of the Trust Territory up to the end of 1951. A detailed report on the first expedition (Shimada 1951) and a comprehensive summary of the first six expeditions (Ego and Otsu 1952) have been published. The present paper aims to report the essential facts concerning the operations of the seventh, eighth, and ninth fleets, without unnecessarily repeating material covered in the two earlier reports.

ORGANIZATION

The seventh and eighth expeditions were very similar in composition and manner of operation, and compared closely with the first expedition of the series. Each consisted of about 25 fishing boats--tuna long-liners of 50 to 250 tons--tended by a 100,000-ton refrigerated cargo vessel primarily designed to carry whale meat from the Antarctic. The seventh fleet was organized around the mothership Settsu Maru, owned by the Nippon Suisan Company, one of Japan's two largest fishing concerns; the eighth expedition with its Tenyo Maru No. 2 (which had previously served as mothership of the first expedition) was operated by the Taiyo Gyogyo Company. The two fleets differed in that most of the fishing boats participating in the eighth expedition were owned by the company which operated the mothership, while the seventh fleet was composed mainly of independently-owned vessels.

The ninth expedition was on a much smaller scale, comparable to the third and sixth fleets, which had been organized by the same company, Nansei Fisheries, with the same mothership, the 577-ton trawler Tenryu Maru. Only three regular long-line vessels worked with this expedition.

In addition to the regular fishing vessels, all three motherships used small (about 30-foot) motor launches to fish long lines. The Settsu Maru had two such boats and the Tenyo Maru No. 2 had one, but as they were operated only part-time on an experimental basis, their contribution to the total catch of the expeditions was negligible. However, the two boats carried by the Tenryu Maru accounted for more than one-fourth of that expedition's catch.

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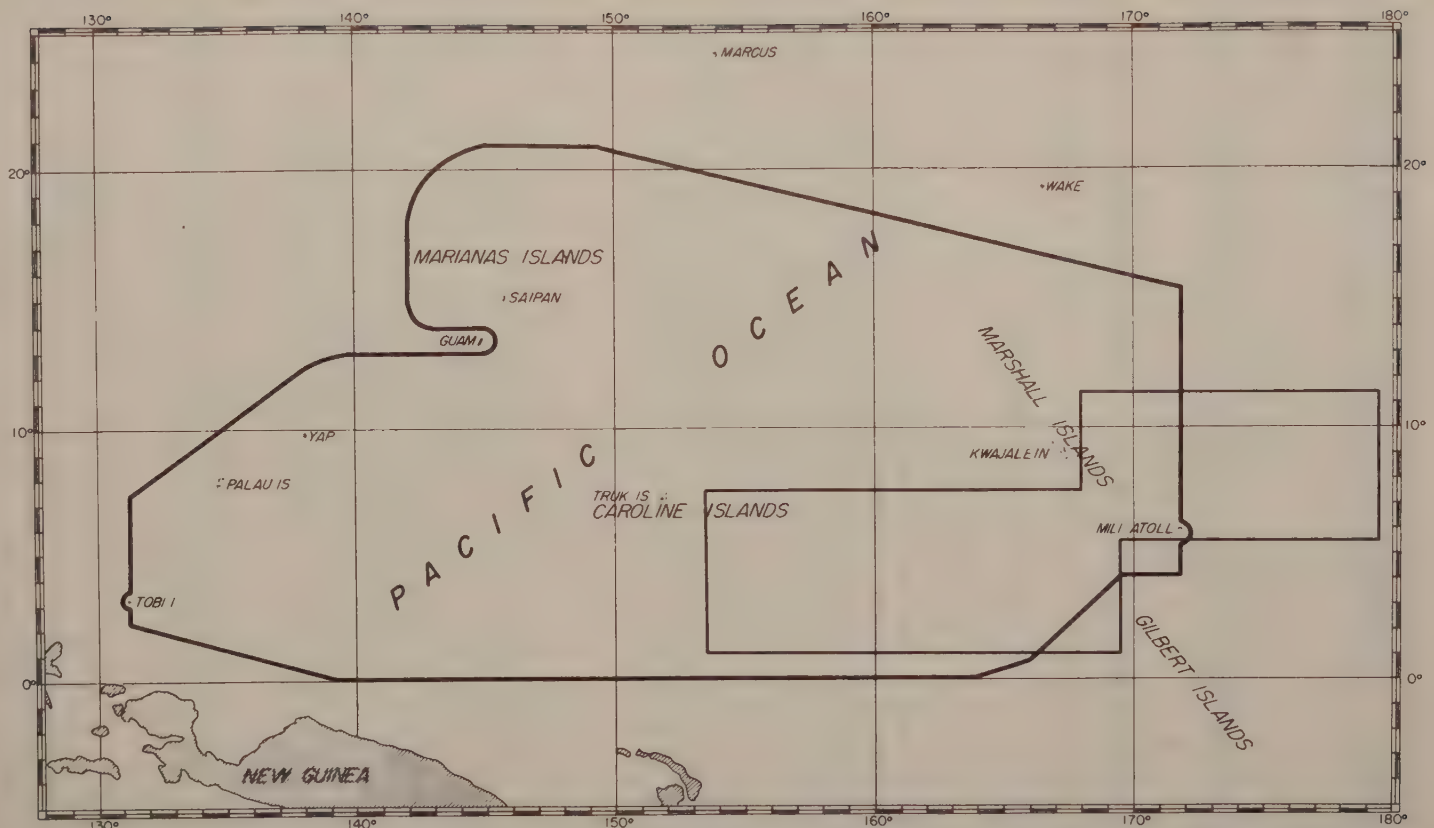
130°
140°
150°
160°
170°
180°
20°
10°
0°
MARCUS
WAKE
MARIANAS ISLANDS
SAIPAN
GUAM I
PACIFIC OCEAN
MARSHALL ISLANDS
KWAJALEIN
YAP
PALAU IS
TRUK IS
CAROLINE ISLANDS
MILI ATOLL
TOBI I
GILBERT ISLANDS
NEW GUINEA

AREA FISHED BY THE SEVENTH, EIGHTH, AND NINTH JAPANESE MOTHERSHIP-TYPE TUNA FLEETS. THE LIGHTER LINE MARKS THE BOUNDARIES WITHIN WHICH ALL THREE EXPEDITIONS OPERATED; THE HEAVIER LINE INDICATES THE BOUNDARIES OF THE U. S. TRUST TERRITORY OF THE PACIFIC ISLANDS.

Table 1 - Essential Data on the Seventh, Eighth, and Ninth Japanese Tuna-Mothership Expeditions

	EXPEDITION		
	Seventh	Eighth	Ninth
Managing concern	Nippon Suisan K. K.	Taiyo Gyogyo K. K.	Nansei Suisan K. K.
Mothership	Settsu Maru (9,329 tons)	Tenyo Maru No. 2 (10,620 tons)	Tenryu Maru (577 tons)
Number of catchers	26 (and 2 boats)	25 (and 1 boat)	3 (and 2 boats)
Left port	May 31, 1951	July 30, 1951	September 3, 1951
Returned to port	September 5, 1951	November 4, 1951	November 1, 1951
Fishing began	June 5, 1951	August 2, 1951	September 17, 1951
Fishing ended	August 26, 1951	October 24, 1951	October 20, 1951
Area fished	1° - 13° N. lat. 153° - 179° E. long.	1° - 13° N. lat. 151° - 179° E. long.	1° - 10° N. lat. 162° - 179° E. long.
Tuna catch	6,228,286 lbs.	4,348,407 lbs.	326,276 lbs.
Spearfish catch	2,149,787 lbs.	1,526,229 lbs.	173,042 lbs.
Sharks and miscellaneous	854,341 lbs.	1,173,497 lbs.	23,404 lbs.
Total catch	9,232,414 lbs.	7,048,133 lbs.	522,722 lbs.
Total boat/days fished	1,312	1,219	126
Average catch rate (fish per 100 hooks per day)	4.47	4.04	3.55

AREA AND PERIOD OF OPERATION

Both the seventh and eighth expeditions fished over nearly the same area, and were on the grounds for about the same length of time. The Settsu Maru sailed from Osaka on May 31 and commenced receiving fish from her catchers on June 12 at 3°04' N. latitude, 155°56' E. longitude. The mothership gradually shifted eastward with its catchers, which were required by SCAP directives to keep within a 200-mile radius of the mothership. The last fish were taken aboard by the ship on August 26 to the east of the southern Marshall Islands at about 7° N. latitude, 179° E. longitude. The Tenyo Maru No. 2 commenced operations August 8 south of Ponape at 3°30' N. latitude, 158° E. longitude, and after moving west as far as 155° E. longitude, began drifting and running to the east and north, following much the same course and winding up its fleet's operations in much the same area as the Settsu Maru. The last fish were taken aboard on October 24.

The Tenryu Maru fleet fished from September 17 to October 20, remaining at all times in the vicinity of the Tenyo Maru fleet and under the control of the inspectors aboard the larger mothership.

OPERATING METHODS

The tuna-fishing vessels, called "catchers" by analogy with whaling fleet practice, fished from 200 to 400 baskets of long lines each day, setting them around dawn and hauling them from midafternoon to midnight. Each catcher came alongside the mothership once in every 10 to 20 days, depending on the success of its fishing and the state of preservation of its catch, to unload its fish and take on supplies. The catchers all used ice to preserve their fish, a few of them also having mechanical refrigeration equipment which was used, not to freeze the catch, but only to keep the ice from melting too fast. The small motor boats fished about 75 to 150 baskets of gear, and returned to the mothership each evening.

The motherships' functions were to receive, freeze, and hold the catch of the fishing boats, and to supply the latter with fuel, crushed ice, bait (frozen sardines and saury), provisions, water, repair facilities, and medical attention. The Tenyo Maru No. 2 with the experience of two previous expeditions managed by the same company, performed these functions smoothly and efficiently, but the Settsu Maru, participating for the first time in an operation of this sort, had some minor difficulties at the beginning. It was found that the fenders with which the mothership was provided were too small, and trouble was experienced in bringing catchers alongside until more adequate fenders were sent down from Japan aboard one of the late-arriving fishing vessels. The second source of trouble was the failure of the catchers to take ice out of the mothership as fast as had been anticipated. This resulted in serious congestion in the holds of the Settsu Maru for a time, and on one occasion it was even found necessary to leave a considerable quantity of ice on the deck overnight with only a covering of straw mats to keep it from melting away.

FIGURE 2 - CREWS OF THE 30-FOOT KAWASAKI BOATS MAKING UP LONG-LINE LEADERS ABOARD THE MOTHERSHIP SETTSU MARU EN ROUTE TO THE FISHING GROUNDS.

FIGURE 3 - ICING A CATCHER BOAT, THE ASAHI MARU NO. 1, ALONGSIDE THE MOTHERSHIP SETTSU MARU.

On the fishing grounds the motherships alternated periods of drifting with short runs to bring them close to the main concentrations of catchers. The degree of control which the fleet manager aboard the mothership had over the movements of the catchers was somewhat greater in the case of the eighth expedition, because of the higher percentage of company-owned vessels in the fleet, but on both major expeditions the fleet managers seemed unwilling or unable to assign catchers to particular fishing grounds against the will of the fishermen. The result was considerable pulling and hauling between the management and the fleet over the direction in which the whole operation was to move. The companies were primarily interested in getting yellowfin tuna which could be exported to the United States at a good profit, while the fishermen wanted to make weight, regardless of whether the catch was composed of yellowfin, big-eyed tuna, marlin, or shark. It was generally believed that yellowfin were more abundant in the southern and western portions of the authorized area, and big-eyed tuna and marlin more numerous to the north and east. Thus, the course of operations was a series of concentrations by the catcher fleet along the northeastern boundary of the 200-mile operating radius, followed by runs by the mothership to close with the fleet, and subsequent shifts of the operating radius to the northeastward. Another factor in this pattern was the desire of the catchers to

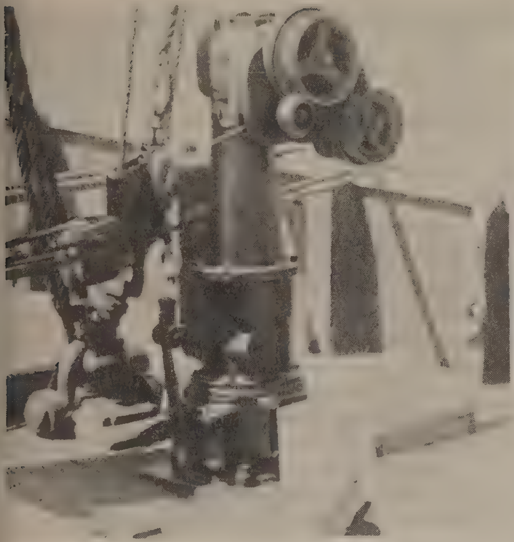

FIGURE 4 - LONG-LINE HAULER INSTALLED IN A 30-FOOT KAWASAKI BOAT.

FIGURE 5 - A SMALL MARLIN BROUGHT TO GAFF ALONGSIDE A LONG-LINE BOAT.

be on big-eyed tuna and marlin grounds at the close of the operation in order to take aboard a big load of high-priced fish for sale in the Japanese fresh-fish markets.

PROCESSING PROCEDURES

The seventh expedition had as its prime objective the production of as much frozen round yellowfin as possible. Four brine tanks, with a total capacity of approximately 30 tons of fish, were used to freeze all first-quality yellowfin and also considerable quantities of big-eyed tuna, albacore, and miscellaneous species. Marlin, shark, broadbill swordfish, large big-eyed tuna, and yellowfin unfit for export were filleted and dry-frozen for the domestic market. About 90 tons of iced fish, mostly large first-grade big-eyed tuna and marlin, were sent to Japan aboard the training ship _Umitaka Maru_ midway through the operation in order to take advantage of good prices prevailing in the Japanese domestic fresh-fish market.

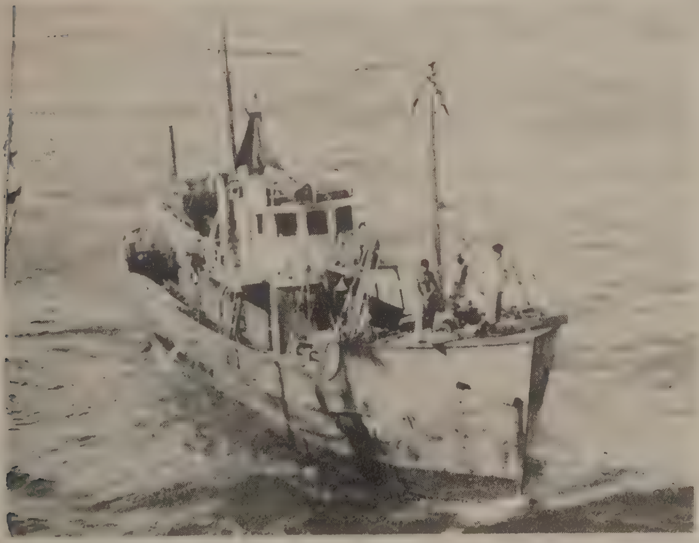

FIGURE 6 - THE _TAIRYO MARU NO. 23_ (55 GROSS TONS) COMING ALONGSIDE THE _TENYO MARU NO. 2_. THIS WAS THE SMALLEST REGULAR LONG-LINE VESSEL PARTICIPATING IN THE EXPEDITIONS.

The eighth expedition started out with the same objective, although with a smaller brine-freezing capacity (one tank of 3.7 ton capacity), and the limited clearance of the racks in the quick-freezing chambers made it necessary to fillet more of the large fish than was done on the Settsu Maru. Midway through this operation, however, developments in the export market caused some revision of processing procedures. First of all, word was received that Nippon Suisan was having trouble finding buyers for the yellowfin frozen aboard the Settsu Maru; then came the news that a high percentage of fish from the fifth expedition had been rejected by United States inspectors; and finally the growing and apparently successful agitation on the West Coast against imports of Japanese tuna made it appear that the export business might soon be completely gone. The reaction to these developments was the dispatch of three cargo vessels (the Banshu Maru No. 22, Bansh Maru No. 32, and Banshu Maru No. 35) to carry over 700 tons of iced fish to Japan. Another 137 tons of iced fish was loaded aboard the mothership in the closing days of the operation, and strenuous efforts were made to salvage everything that coul be sold in the Japanese market. Unlike the Settsu Maru, the Tenyo Maru No. 2 crew had from the start been recovering and saving all the scrap meat from the heads and skeletons of the filleted tunas and marlin. Towards the end of the operation even the heads and the scraped bones were saved to be carried back to Japan an sold to eel culturists as feed.

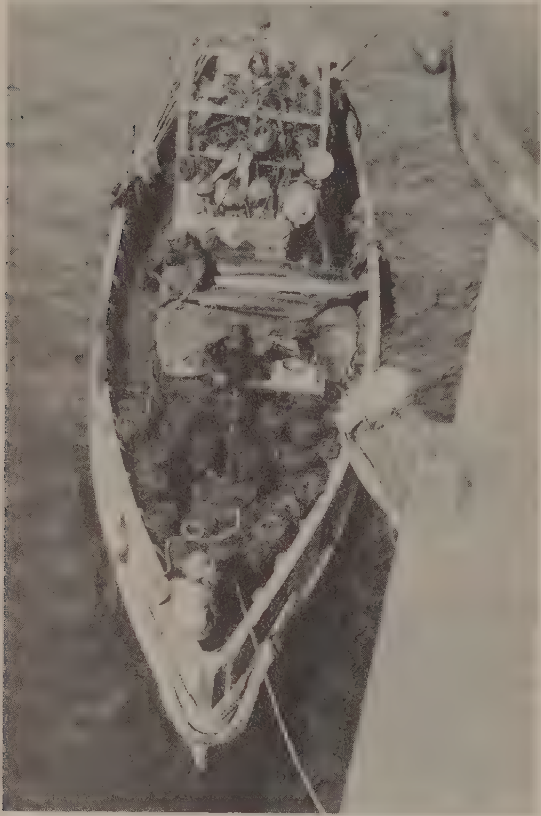

FIGURE 7 - A 30-FOOT KAWASAKI BOAT BRINGING A MORNING'S CATCH OF MARLIN AND TUNA TO THE MOTHERSHIP SETTSU MARU. NOTE SKATES OF LINE FORWARD, LINE HAULER AMIDSHIPS, GLASS FLOATS IN CORRAL ATOP THE ENGINEHOUSE, AND FLAG POLES IN RACK AFT.

No direct observations were made of the fish-processing techniques employed on the Tenryu Maru, mothership of the ninth expedition. It is known, however, that a failure of the refrigeration system of this vessel resulted in the loss of a large part of the catch and made the expedition quite profitless to the vessels that participated in it.

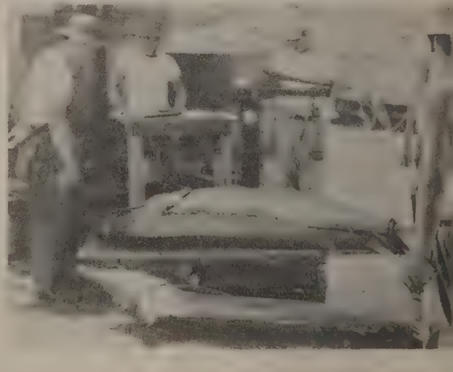

FIGURE 8 - WEIGHING BLACK MARLIN ABOARD THE MOTHERSHIP TENYO MARU NO. 2.

RESULTS OF THE EXPEDITIONS

The seventh expedition began its operations with a goal of approximately 8,270,000 pounds of fish, and this figure was exceeded with only a few extra days of operation over the originally-scheduled period. The over-all average catch rate (fish per 100 hook er day) for this expedition was 4.47, of which 2.09 were yellowfin tuna. The ighth expedition, operating almost exactly the same number of days and with the ame number of catchers in its leet, took about 7,048,130 ounds for an average catch ate of 4.04, of which 1.64 ere yellowfin tuna. The report f the Taiyo Gyogyo Company on he eighth expedition blamed hese rather poor results on he seventh expedition's havng reduced the stocks of fish vailable for capture in the rea, but the consensus of the ishermen seemed to be that he low catch rates were largey due to the poor quality of he bait supplied by the mothership. The much smaller ninth xpedition made a total catch f 522,722 pounds with an even ower average catch rate of .55, of which 1.40 were yellowin tuna. These results may e compared with the over-all verage for the first nine expeditions, which caught 4.10 ish of all species per 100 hooks per day, of which 2.14 were yellowfin tuna. It s apparent that these last three expeditions found yellowfin tuna scarcer than heir predecessors although, as indicated earlier, the fishermen concentrated in reas where they could make better weight on big-eyed tuna and marlin.

Table 2 - Catch Rates by the Seventh, Eighth, and Ninth Japanese Tuna-Mothership Expeditions

Species	Number of Fish Caught Per 100 Hooks Per Day Fished			
	Expedition			Average For Expeditions 1 Through 9
	7th	8th	9th	
Yellowfin tuna ..	2.09	1.64	1.40	2.14
Big-eyed tuna ...	0.93	0.80	0.88	0.62
Albacore tuna ...	0.06	0.16	0.10	0.07
Black tuna	<0.01	<0.01	<0.01	<0.01
Skipjack tuna ...	0.07	0.06	0.08	0.05
Black marlin	0.60	0.48	0.75	0.53
White marlin	<0.01	<0.01	<0.01	<0.01
Sailfish and short-nosed spearfish	0.04	0.04	0.03	0.04
Broadbill swordfish	<0.01	<0.01	<0.01	<0.01
Striped marlin ..	<0.01	<0.01	<0.01	<0.01
Sharks	0.57	0.75	0.14	0.54
Others	0.09	0.10	0.16	0.08
Total	4.47	4.04	3.55	4.10

< LESS THAN.

CONCLUSIONS

The postwar Japanese mothership-type tuna expeditions to Trust Territory waers were a response to a peculiar set of conditions existing at the time, and it appeared doubtful that any similar large-scale operations would be undertaken after

able 3 - Prices Paid to Catchers of the Seventh Japanese Tuna-Mothership Expedition

Species	Grade	Price Per Pound[1]	Remarks
		U.S. Cents	
ellowfin and Albacore Tuna	A	6.7	Round fish
	B	6.0	
	C	5.0	
ig-eyed Tuna	A	5.4	Gutted
	B	5.0	
	C	4.4	
arlin and others	A	4.7	Marlin gutted, small miscellaneous fish round
	B	3.7	
hark	-	2.0	Gutted and beheaded

NOTE: VALUES CONVERTED AT THE RATE OF 360 YEN PER US$1, AND WEIGHT ON THE BASIS OF 8.27 POUNDS PER *KAN*.

he ratification of the Peace Treaty had removed the restrictions upon the free ovement of Japanese fishing vessels. Independent boat owners and fishermen preer to operate singly rather than with a fleet because of the greater freedom of ction, the shorter duration of the voyages, and the generally higher prices re-

Table 4 - Prices Paid to Catchers of the Eighth Japanese Tuna-Mothership Expedition

Species	Grade	Price Per Pound[1]	Remarks
		U.S. Cents	
Yellowfin and Albacore tuna	A	7.0	Albacore round; yellowfin gutted during latter part of operation
	B	5.7	
	C	4.4	
	D	2.0	
Big-eyed tuna and Spearfish	A	5.4	Gutted
	B	4.0	
	C	2.0	
Small Yellowfin tuna	A	5.4	Round fish
	B	2.0	
Small Big-eyed tuna	A	4.4	Round fish
	B	2.0	
Wahoo	-	5.0	Round fish
Barracuda, dolphin, and sailfish	-	2.7	
Skipjack tuna	-	4.4	
Shark	-	2.0	Gutted

[1]/VALUES CONVERTED AT THE RATE OF 360 YEN PER US$1, AND WEIGHT ON THE BASIS OF 8.27 POUNDS PER KAN.

ceived when fish are delivered directly to Japanese homeland markets. On the other hand, the big fishing companies seek employment for their idle freezerships between Antarctic whaling seasons, and there are many smaller long-liners which, lacking land bases at which to obtain fuel and ice, cannot fish the distant tropical tuna grounds without the support of a mothership.

Opinion among the supervisory personnel on the seventh and eighth expeditions concerning the future of Japanese tuna fishing in southern Pacific waters ran mainly along two lines. Men experienced in the prewar floating crab-cannery fishery in northern Pacific waters felt that similar shipboard canning of tuna could be carried on successfully and that it would result in a more efficient utilization of both fish and cargo space than the presen freezing operations. There is little demand for canned fish in Japan, however, so the practicability of such a development would hinge upon the condition of the export market. Another school of thought held that the solution to the problem lay in building 300- or 400-ton long-liners with greater cruising range, better refrigeration facilities, and more adequate crew accommodations than the pre ent boats. Such vessels would be capable of operating independently all over the South Seas and could bring back big fares of high-quality, high-priced fresh fish for the Japanese domestic market.

FIGURE 9 - SQUARING AWAY THE DECK OF THE MOTHERSHIP _TENYO MARU NO. 2_ PREPARATORY TO LEAVING THE FISHING GROUNDS. FILLET FREEZING PANS IN THE FOREGROUND.

Recent reports from Japan indicate that there is, in fact, a trend toward the construction of larger long-line boats equipped with brine tanks for the precooling of their catch. At the same time, the Japanese Government has shown a desire to reserve for single-vessel operations the area fished by mothership fleets under

SCAP regulations, forcing the motherships and their catcher boats out into more distant and less thoroughly-explored grounds. This policy would seem likely to have a discouraging effect on small-scale mothership enterprises like the ninth expedition, but it does not appear to have held back the big operators, as is evidenced by the fact that in the first summer season after the ratification of the Peace Treaty both the Nippon Suisan and the Taiyo Gyogyo companies sent large fleets into Southeast Asian waters. This region--the Celebes, Banada, and Flores Seas and the eastern Indian Ocean--proved to have rich tuna grounds as was shown by Japanese explorations before and during World War II. It will be interesting to see whether the results of this latest expansion of the high seas tuna fishery will be sufficiently rewarding to make mothership-type operations a permanent feature of the Japanese tuna industry.

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Isolation of Ascorbic Acid and Rhamnosides from Sea Water

THE presence in sea water of a substance that is physiologically active in oysters and that can be measured photometrically with *n*-ethyl carbazole has been reported by Collier, Ray, and Magnitzky (*1*). Comparison of the *n*-ethyl carbazole absorption spectrum formed in sea water with spectra of pure carbohydrates led to the conclusion that more than one carbohydrate was taking part in the determination. Methods to isolate and identify the compounds were then sought.

The carbohydrates were removed from sea water onto a column of activated charcoal, as described by Whistler and Durso (*2*). They were then removed from the column by elution with ethanol. Evaporation of the eluate gave two white crystalline compounds, which were separated by their different solubilities in 50% ethanol. The substance that precipitates in 50% ethanol, as yet unidentified, gives some indication of being a rhamnoside.

Evaporation of the alcohol-water mixture produced a crystalline compound which, in water solution, gave an ultraviolet absorption spectrum similar to that reported for dehydroascorbic acid by Herbert, Hirst, Percival, Reynolds, and Smith (*3*).

In order to study the similarity between the absorption spectra more closely, we prepared a solution of dehydroascorbic acid by oxidizing ascorbic acid in the presence of Cu ++. The absorption spectrum of this oxidation product agreed very closely with that of our compound from sea water, both in water and in 79% H_2SO_4. The colors resulting from the reaction of the oxidized ascorbic acid and from our sample with 2,4-dinitrophenyldydrazine exhibited the same spectra. The amount of sample available was too small to allow any extensive recrystallization and, therefore, any comparison of melting points with those reported in the literature was not feasible.

Absorption spectra from samples of sea water taken in various parts of the Gulf of Mexico agreed closely with the spectra we had run on oxidized ascorbic acid. We concluded from these curves that the vitamin is present in the sea largely in the form of dehydroascorbic acid. The amounts of vitamin as shown by the absorption spectra did not agree with the calculated amounts of carbohydrate found by the *n*-ethyl carbazole method. The discrepancy is probably due to the as yet unidentified "rhamnoside," which shows some color with *n*-ethyl carbazole. This "rhamnoside" is by far the most abundant carbohydrate in sea water. We have found concentrations as high as 0.1 g/l of the "rhamnoside" from inshore waters.

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